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Tang et al.

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(54) **CHANNEL RASTER AND SYNCHRONIZATION SIGNAL RASTER FOR NR UNLICENSED SPECTRUM**

(52) **U.S. Cl.**
CPC **H04W 56/001** (2013.01); **H04L 27/26025** (2021.01); **H04L 27/2607** (2013.01)

(58) **Field of Classification Search**
CPC H04W 56/001; H04L 27/26025; H04L 27/2607; H04L 5/001; H04L 27/261; H04L 5/005; H04L 5/0092; H04L 5/0007
See application file for complete search history.

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(56) **References Cited**

U.S. PATENT DOCUMENTS

2018/0048435 A1 2/2018 Toufiqul
2018/0139084 A1 5/2018 Jung et al.
(Continued)

(73) Assignee: **APPLE INC.**, Cupertino, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 277 days.

FOREIGN PATENT DOCUMENTS

WO 2018213678 A1 11/2018
WO 2019050197 A1 3/2019

(21) Appl. No.: **17/593,080**

OTHER PUBLICATIONS

(22) PCT Filed: **May 13, 2020**

PCT/US2020/032736, International Search Report and Written Opinion, Nov. 19, 2020, 33 pages.

(86) PCT No.: **PCT/US2020/032736**

(Continued)

§ 371 (c)(1),

(2) Date: **Sep. 8, 2021**

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(87) PCT Pub. No.: **WO2020/232164**

(57) **ABSTRACT**

PCT Pub. Date: **Nov. 19, 2020**

Systems and methods for determining channel raster(s) and synchronization signal raster(s) for New Radio (NR) unlicensed spectrum are disclosed herein. For each of a plurality of data objects an NR channel raster position is determined using Absolute Radio Frequency Channel Number (NR-ARFCN) numbers. For each corresponding NR channel. Global Synchronization Channel Numbers (GSCNs), a number of Physical Resource Blocks (PRBs) based on channel subcarrier spacing (SCS). NR channel raster position placement, channel edges, synchronization signal and physical broadcast channel (SSB) edges, and an SSB raster position are calculated. The plurality of data objects may then be down selected based on e.g., corresponding Long Term

(65) **Prior Publication Data**

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Related U.S. Application Data

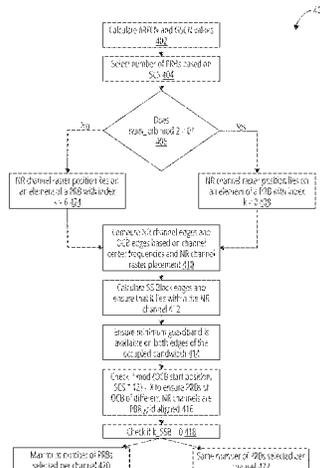
(60) Provisional application No. 62/847,770, filed on May 14, 2019.

(51) **Int. Cl.**

H04W 56/00 (2009.01)

H04L 27/26 (2006.01)

(Continued)



Evolution (LTE) channel raster positions and/or entries of a second plurality of data objects calculated for NR channels that use a second SCS.

16 Claims, 26 Drawing Sheets
(19 of 26 Drawing Sheet(s) Filed in Color)

(56)

References Cited

U.S. PATENT DOCUMENTS

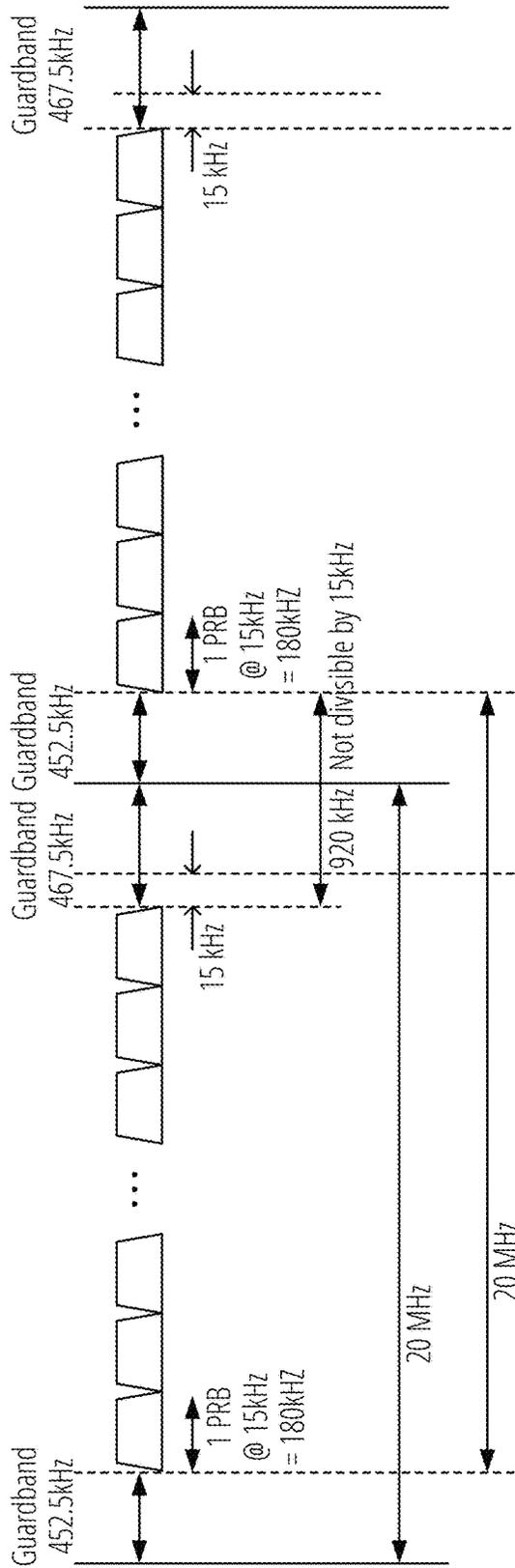
2018/0338304	A1	11/2018	Gheorghiu et al.	
2019/0028315	A1	1/2019	Park et al.	
2019/0103931	A1	4/2019	Yi et al.	
2019/0124609	A1	4/2019	Gheorghiu et al.	
2019/0159148	A1*	5/2019	Jung	H04W 56/006
2020/0084739	A1*	3/2020	Si	H04L 5/0048
2021/0037488	A1*	2/2021	Ko	H04W 56/001

OTHER PUBLICATIONS

Huawei, Hisilicon, "Performance enhancements for NB-IoT coexistence with NR", R1-1903912, 3GPP TSG RAN WG1 Meeting #96bis, Xi'an, China, Agenda Item 6.2.2.4, Apr. 8-12, 2019, 5 pages.

* cited by examiner

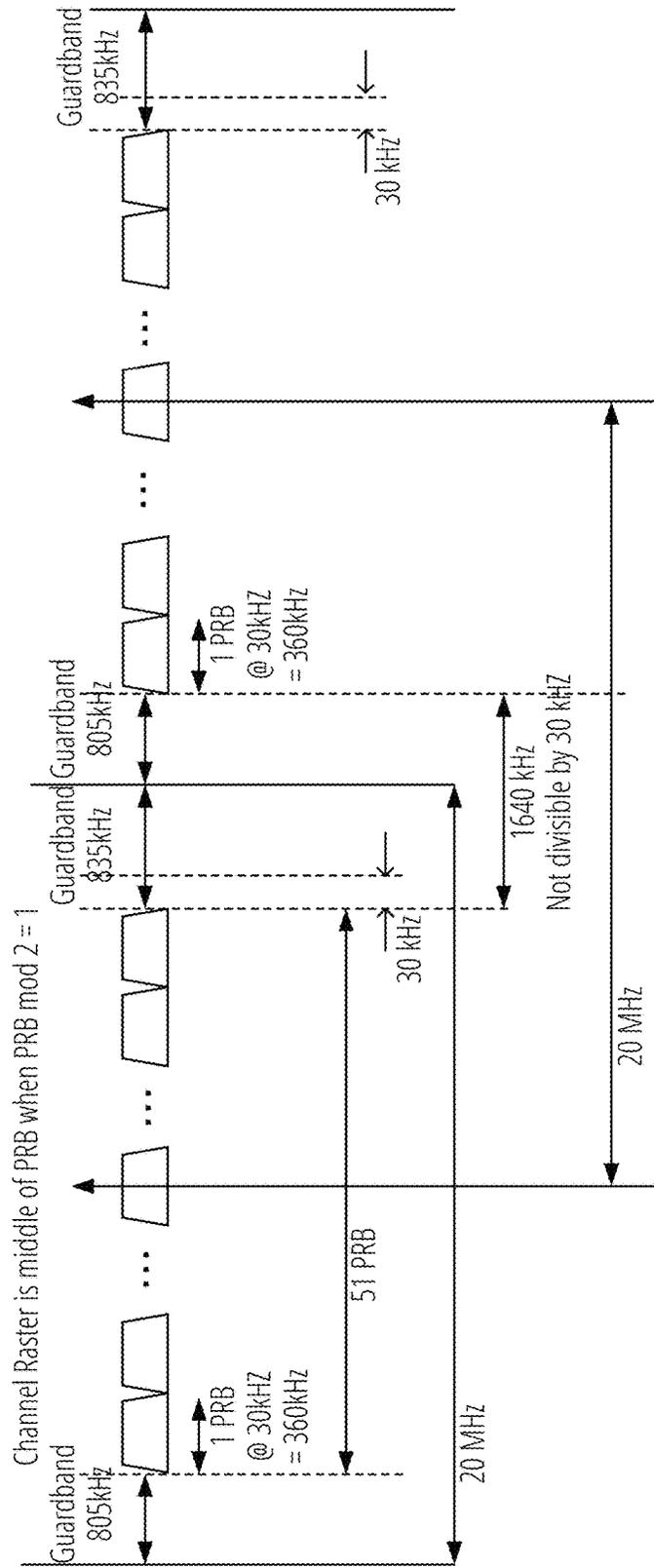
100



Note: Bandwidths not according to scale

FIG. 1

200



Note: Bandwidths not according to scale

FIG. 2

300

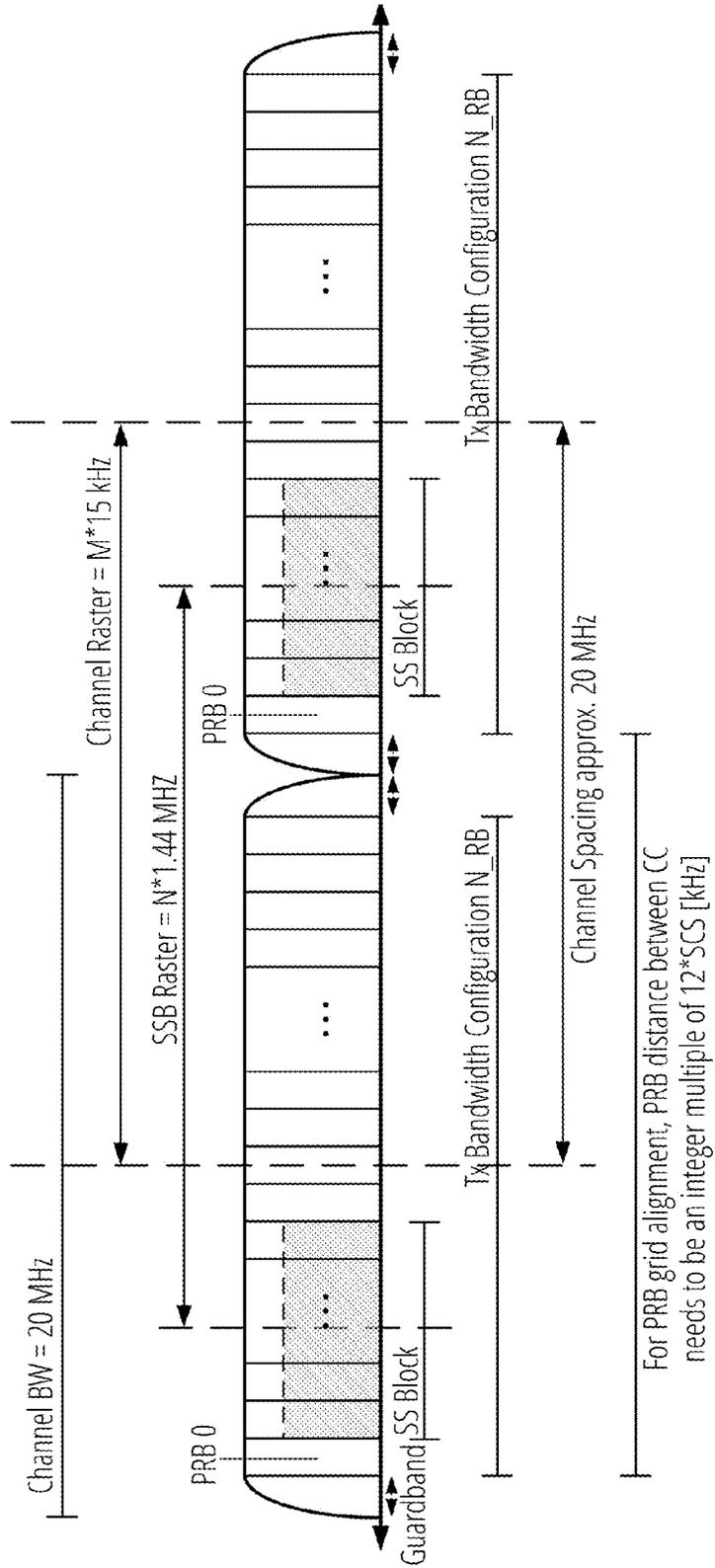


FIG. 3

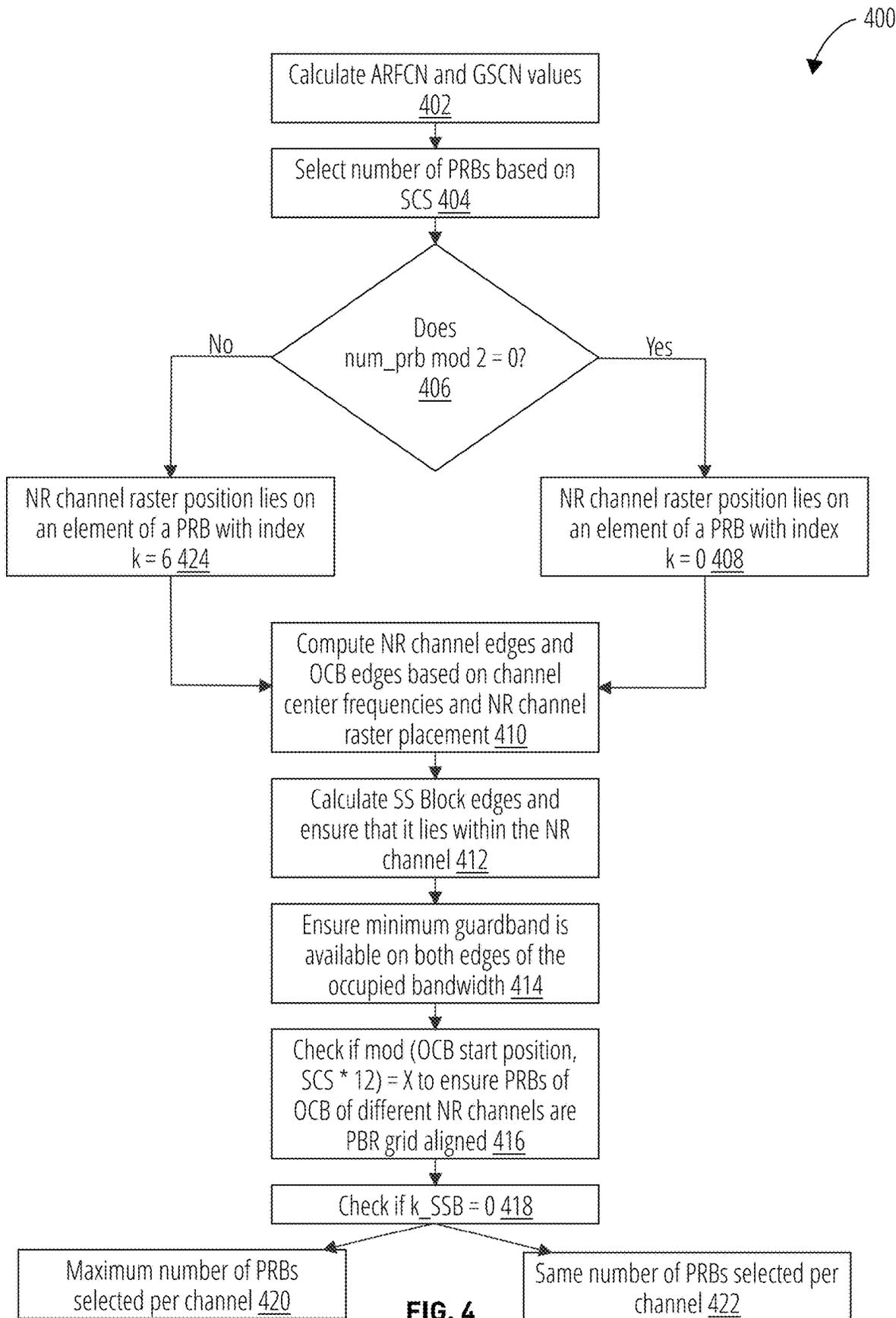


FIG. 4

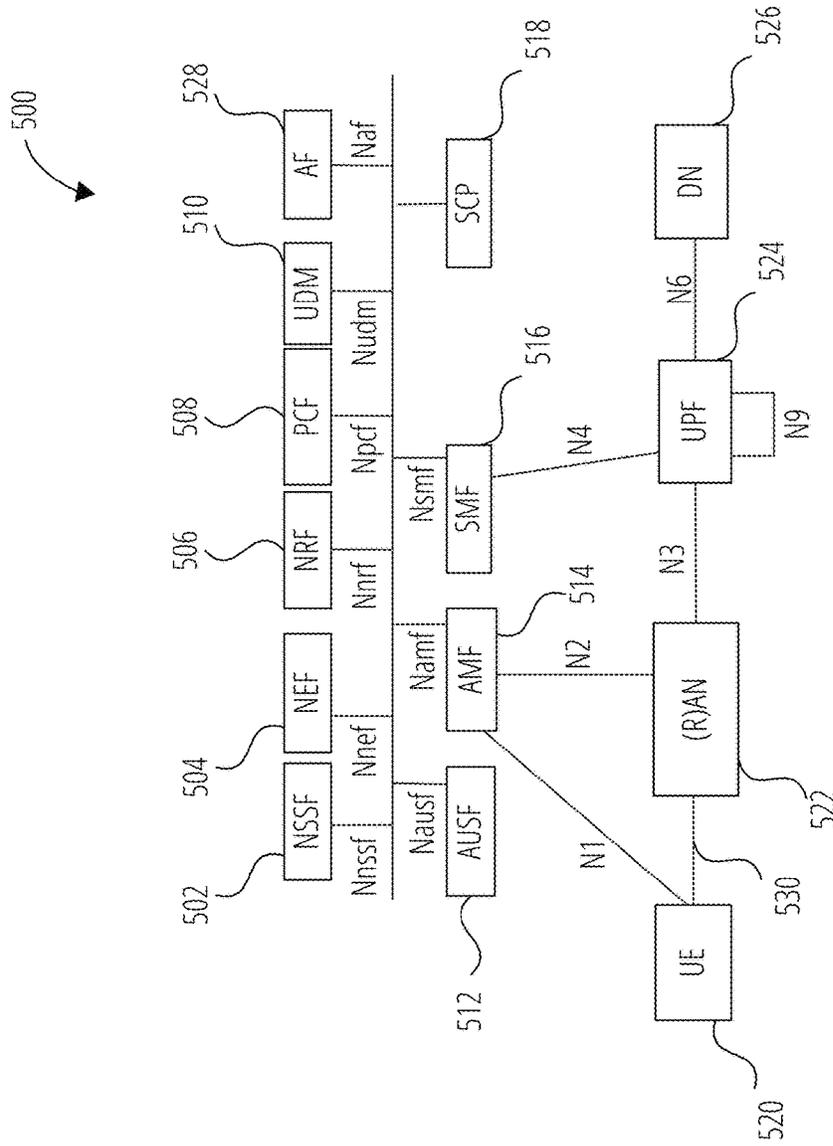


FIG. 5

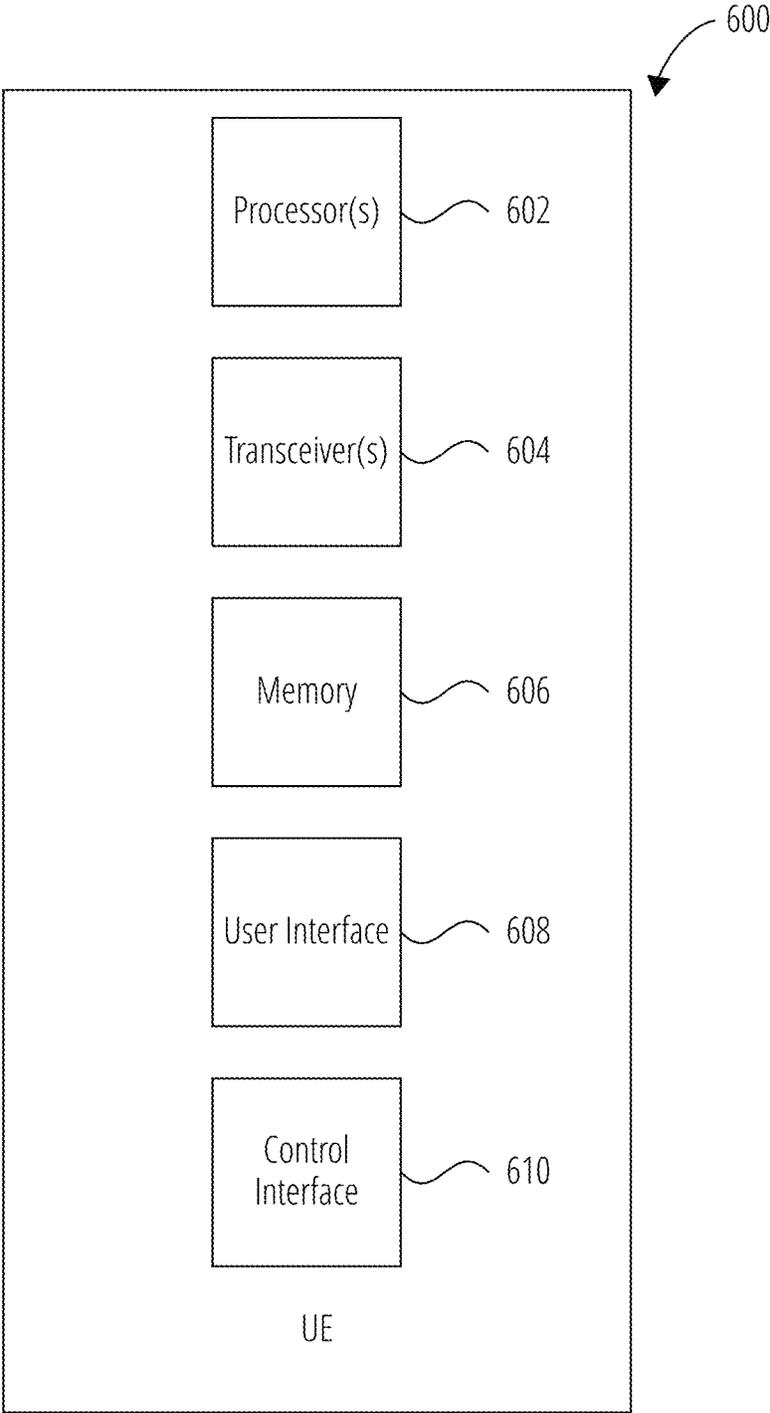


FIG. 6

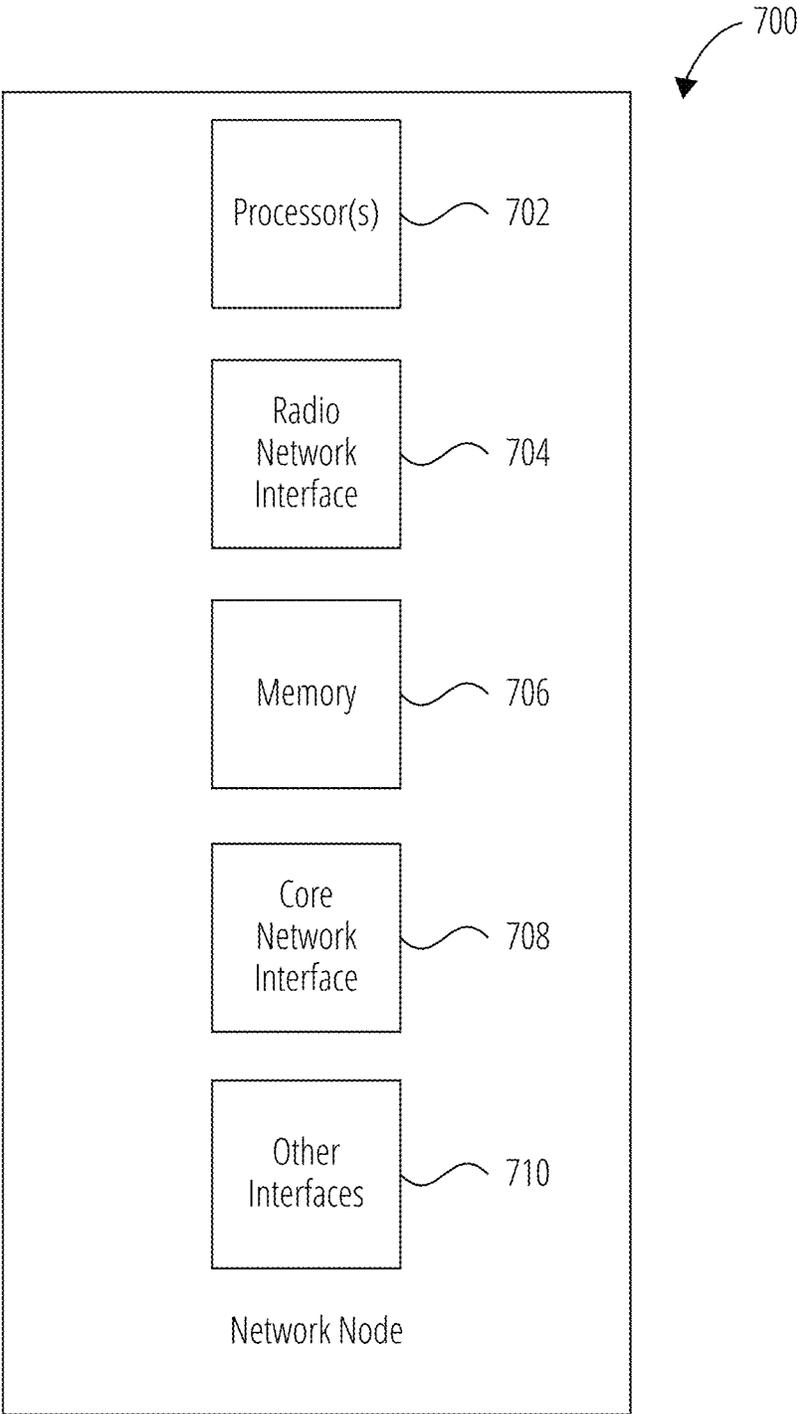


FIG. 7

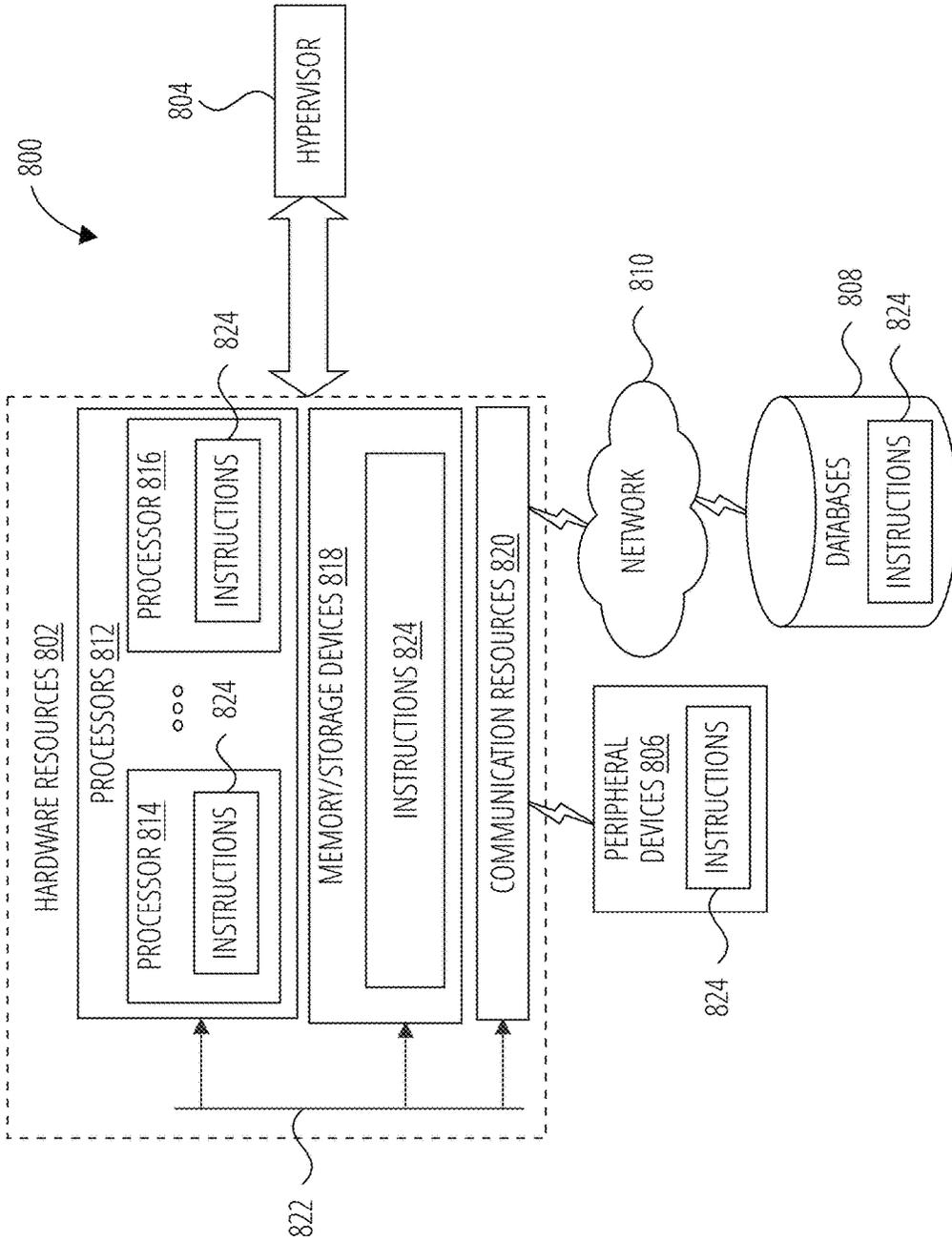


FIG. 8

900

Table 8

Entry No.	UNII-Band	LTE Chn Raster [kHz]	BW [MHz]	Data SCS [kHz]	NR Chn Raster [kHz]	NR-ARFCN (N _{RRF})	N_PRB	SS Raster [kHz]	GSCN	Min GSCN	Max GSCN
1	1	5160000	20/60/100	30	5160000	744000	50	5155680	8996	8996	9002
2	1	5180000	20/60/100	30	5180160	745344	50	5175840	9010	9010	9016
3	1	5200000	20/60/100	30	5199960	746664	50	5194560	9023	9023	9030
4	1	5220000	20/60/100	30	5220120	748008	50	5214720	9037	9037	9044
5	1	5240000	20/60/100	30	5239920	749328	50	5234880	9051	9051	9058
6	1	5260000	20/60/100	30	5260080	750672	50	5255040	9065	9065	9072
7	1	5280000	20/60/100	30	5279880	751992	50	5275200	9079	9079	9086
8	1	5300000	20/60/100	30	5300040	753336	50	5295360	9093	9093	9100
9	1	5320000	20/60/100	30	5319840	754656	50	5315520	9107	9107	9113
10	1	5320000	20/60/100	30	5320020	754668	51	5315520	9107	9107	9114
11	1	5320000	20/60/100	30	5320200	754680	50	5315520	9107	9107	9114
12	1	5340000	20/60/100	30	5340000	756000	50	5335680	9121	9121	9127
13	2	5480000	20/60/100	30	5480040	765336	50	5475360	9218	9218	9225
14	2	5500000	20/60/100	30	5499840	766656	50	5495520	9232	9232	9238
15	2	5500000	20/60/100	30	5500020	766668	51	5495520	9232	9232	9239
16	2	5500000	20/60/100	30	5500200	766680	50	5495520	9232	9232	9239
17	2	5520000	20/60/100	30	5520000	768000	50	5515680	9246	9246	9252
18	2	5540000	20/60/100	30	5540160	769344	50	5535840	9260	9260	9266
19	2	5560000	20/60/100	30	5559960	770664	50	5554560	9273	9273	9280
20	2	5580000	20/60/100	30	5580120	772008	50	5574720	9287	9287	9294
21	2	5600000	20/60/100	30	5599920	773328	50	5594880	9301	9301	9308
22	2	5620000	20/60/100	30	5620080	774672	50	5615040	9315	9315	9322

FIG. 9A

900
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23	2	5640000	20/60/100	30	5639880	775992	50	5635200	9329	9336
24	2	5660000	20/60/100	30	5660040	777336	50	5655360	9343	9350
25	2	5680000	20/60/100	30	5679840	778656	50	5675520	9357	9363
26	2	5680000	20/60/100	30	5680020	778668	51	5675520	9357	9364
27	2	5680000	20/60/100	30	5680200	778680	50	5675520	9357	9364
28	2	5700000	20/60/100	30	5700000	780000	50	5695680	9371	9377
29	2	5720000	20/60/100	30	5720160	781344	50	5715840	9385	9391
30	3	5745000	20/60/100	30	5745000	783000	50	5740320	9402	9409
31	3	5765000	20/60/100	30	5765160	784344	50	5760480	9416	9423
32	3	5785000	20/60/100	30	5784960	785664	50	5780640	9430	9436
33	3	5805000	20/60/100	30	5805120	787008	50	5800800	9444	9450
34	3	5825000	20/60/100	30	5824920	788328	50	5819520	9457	9464
35	3	5845000	20/60/100	30	5845080	789672	50	5839680	9471	9478
36	3	5865000	20/60/100	30	5864880	790992	50	5859840	9485	9492
37	3	5885000	20/60/100	30	5885040	792336	50	5880000	9499	9506
38	3	5905000	20/60/100	30	5904840	793656	50	5900160	9513	9520
39	3	5905000	20/60/100	30	5905020	793668	51	5900160	9513	9520
40	3	5905000	20/60/100	30	5905200	793680	50	5900160	9513	9520
41	1	5170000	40/80	30	5169900	744660	105	5155680	8996	9016
42	1	5190000	40/80	30	5190060	746004	105	5175840	9010	9030
43	1	5210000	40/80	30	5209860	747324	105	5194560	9023	9044
44	1	5230000	40/80	30	5230020	748668	105	5214720	9037	9058
45	1	5250000	40/80	30	5249820	749988	105	5234880	9051	9072
46	1	5250000	40/80	30	5250000	750000	106	5234880	9051	9072
47	1	5250000	40/80	30	5250180	750012	105	5234880	9051	9072
48	1	5270000	40/80	30	5269980	751332	105	5255040	9065	9086
49	1	5290000	40/80	30	5290140	752676	105	5275200	9079	9100

FIG. 9B

900

50	1	5310000	40/80	30	5309940	753996	105	5295360	9093	9093	9113
51	1	5330000	40/80	30	5330100	755340	105	5315520	9107	9107	9127
52	2	5490000	40/80	30	5489940	765996	105	5475360	9218	9218	9238
53	2	5510000	40/80	30	5510100	767340	105	5495520	9232	9232	9252
54	2	5530000	40/80	30	5529900	768660	105	5515680	9246	9246	9266
55	2	5550000	40/80	30	5550060	770004	105	5535840	9260	9260	9280
56	2	5570000	40/80	30	5569860	771324	105	5554560	9273	9273	9294
57	2	5590000	40/80	30	5590020	772668	105	5574720	9287	9287	9308
58	2	5610000	40/80	30	5609820	773988	105	5594880	9301	9301	9322
59	2	5610000	40/80	30	5610000	774000	106	5594880	9301	9301	9322
60	2	5610000	40/80	30	5610180	774012	105	5594880	9301	9301	9322
61	2	5630000	40/80	30	5629980	775332	105	5615040	9315	9315	9336
62	2	5650000	40/80	30	5650140	776676	105	5635200	9329	9329	9350
63	2	5670000	40/80	30	5669940	777996	105	5655360	9343	9343	9363
64	2	5690000	40/80	30	5690100	779340	105	5675520	9357	9357	9377
65	2	5710000	40/80	30	5709900	780660	105	5695680	9371	9371	9391
66	3	5755000	40/80	30	5754900	783660	105	5740320	9402	9402	9422
67	3	5775000	40/80	30	5775060	785004	105	5760480	9416	9416	9436
68	3	5795000	40/80	30	5794860	786324	105	5780640	9430	9430	9450
69	3	5815000	40/80	30	5815020	787668	105	5800800	9444	9444	9464
70	3	5835000	40/80	30	5834820	788988	105	5819520	9457	9457	9478
71	3	5835000	40/80	30	5835000	789000	106	5819520	9457	9457	9478
72	3	5835000	40/80	30	5835180	789012	105	5820960	9458	9458	9478
73	3	5855000	40/80	30	5854980	790332	105	5839680	9471	9471	9492
74	3	5875000	40/80	30	5875140	791676	105	5859840	9485	9485	9506
75	3	5895000	40/80	30	5894940	792996	105	5880000	9499	9499	9520

FIG. 9C

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Table 9

Entry No.	k_SSB	RB Offset (Left)	RB Offset (Right)	Occ. Chn-Start [kHz]	Occ. Chn-End [kHz]	Left Guard [kHz]	Right Guard [kHz]	SSB Start [kHz]	SSB End [kHz]
1	0	3	27	5151000	5168970	985	1015	5152080	5159250
2	0	3	27	5171160	5189130	1145	855	5172240	5179410
3	0	0	30	5190960	5208930	945	1055	5190960	5198130
4	0	0	30	5211120	5229090	1105	895	5211120	5218290
5	0	1	29	5230920	5248890	905	1095	5231280	5238450
6	0	1	29	5251080	5269050	1065	935	5251440	5258610
7	0	2	28	5270880	5288850	865	1135	5271600	5278770
8	0	2	28	5291040	5309010	1025	975	5291760	5298930
9	0	3	27	5310840	5328810	825	1175	5311920	5319090
10	0	3	28	5310840	5329170	825	815	5311920	5319090
11	0	2	28	5311200	5329170	1185	815	5311920	5319090
12	0	3	27	5331000	5348970	985	1015	5332080	5339250
13	0	2	28	5471040	5489010	1025	975	5471760	5478930
14	0	3	27	5490840	5508810	825	1175	5491920	5499090
15	0	3	28	5490840	5509170	825	815	5491920	5499090
16	0	2	28	5491200	5509170	1185	815	5491920	5499090
17	0	3	27	5511000	5528970	985	1015	5512080	5519250
18	0	3	27	5531160	5549130	1145	855	5532240	5539410
19	0	0	30	5550960	5568930	945	1055	5550960	5558130
20	0	0	30	5571120	5589090	1105	895	5571120	5578290
21	0	1	29	5590920	5608890	905	1095	5591280	5598450
22	0	1	29	5611080	5629050	1065	935	5611440	5618610
23	0	2	28	5630880	5648850	865	1135	5631600	5638770

FIG. 10A

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24	0	0	2	28	5651040	5669010	1025	975	5651760	5658930
25	0	3	27	27	5670840	5688810	825	1175	5671920	5679090
26	0	3	28	28	5670840	5689170	825	815	5671920	5679090
27	0	2	28	28	5671200	5689170	1185	815	5671920	5679090
28	0	3	27	27	5691000	5708970	985	1015	5692080	5699250
29	0	3	27	27	5711160	5729130	1145	855	5712240	5719410
30	0	2	28	28	5736000	5753970	985	1015	5736720	5743890
31	0	2	28	28	5756160	5774130	1145	855	5756880	5764050
32	0	3	27	27	5775960	5793930	945	1055	5777040	5784210
33	0	3	27	27	5796120	5814090	1105	895	5797200	5804370
34	0	0	30	30	5815920	5833890	905	1095	5815920	5823090
35	0	0	30	30	5836080	5854050	1065	935	5836080	5843250
36	0	1	29	29	5855880	5873850	865	1135	5856240	5863410
37	0	1	29	29	5876040	5894010	1025	975	5876400	5883570
38	0	2	28	28	5895840	5913810	825	1175	5896560	5903730
39	0	2	29	29	5895840	5914170	825	815	5896560	5903730
40	0	1	29	29	5896200	5914170	1185	815	5896560	5903730
41	0	3	82	82	5151000	5188770	985	1215	5152080	5159250
42	0	3	82	82	5171160	5208930	1145	1055	5172240	5179410
43	0	0	85	85	5190960	5228730	945	1255	5190960	5198130
44	0	0	85	85	5211120	5248890	1105	1095	5211120	5218290
45	0	1	84	84	5230920	5268690	905	1295	5231280	5238450
46	0	1	85	85	5230920	5269050	905	935	5231280	5238450
47	0	0	85	85	5231280	5269050	1265	935	5231280	5238450
48	0	1	84	84	5251080	5288850	1065	1135	5251440	5258610
49	0	1	84	84	5271240	5309010	1225	975	5271600	5278770
50	0	2	83	83	5291040	5328810	1025	1175	5291760	5298930

FIG. 10B

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↙

51	0	2	83	5311200	5348970	1185	1015	5311920	5319090
52	0	2	83	5471040	5508810	1025	1175	5471760	5478930
53	0	2	83	5491200	5528970	1185	1015	5491920	5499090
54	0	3	82	5511000	5548770	985	1215	5512080	5519250
55	0	3	82	5531160	5568930	1145	1055	5532240	5539410
56	0	0	85	5550960	5588730	945	1255	5550960	5558130
57	0	0	85	5571120	5608890	1105	1095	5571120	5578290
58	0	1	84	5590920	5628690	905	1295	5591280	5598450
59	0	1	85	5590920	5629050	905	935	5591280	5598450
60	0	0	85	5591280	5629050	1265	935	5591280	5598450
61	0	1	84	5611080	5648850	1065	1135	5611440	5618610
62	0	1	84	5631240	5669010	1225	975	5631600	5638770
63	0	2	83	5651040	5688810	1025	1175	5651760	5658930
64	0	2	83	5671200	5708970	1185	1015	5671920	5679090
65	0	3	82	5691000	5728770	985	1215	5692080	5699250
66	0	2	83	5736000	5773770	985	1215	5736720	5743890
67	0	2	83	5756160	5793930	1145	1055	5756880	5764050
68	0	3	82	5775960	5813730	945	1255	5777040	5784210
69	0	3	82	5796120	5833890	1105	1095	5797200	5804370
70	0	0	85	5815920	5853690	905	1295	5815920	5823090
71	0	0	86	5815920	5854050	905	935	5815920	5823090
72	0	3	82	5816280	5854050	1265	935	5817360	5824530
73	0	0	85	5836080	5873850	1065	1135	5836080	5843250
74	0	0	85	5856240	5894010	1225	975	5856240	5863410
75	0	1	84	5876040	5913810	1025	1175	5876400	5883570

FIG. 10C

1100

Table 12

UNII-Band	LTE Chn Raster [kHz]	BW [MHz]	Data SCS [kHz]	NR Chn Raster [kHz]	NR-ARFCN (N _{REF})	N_PRB	SS Raster [kHz]	GSCN	Min GSCN	Max GSCN
1	5160000	20/60/100	30	5160000	744000	50	5155680	8996	8996	9002
1	5180000	20/60/100	30	5180160	745344	50	5175840	9010	9010	9016
1	5200000	20/60/100	30	5199960	746664	50	5194560	9023	9023	9030
1	5220000	20/60/100	30	5220120	748008	50	5214720	9037	9037	9044
1	5240000	20/60/100	30	5239920	749328	50	5234880	9051	9051	9058
1	5260000	20/60/100	30	5260080	750672	50	5255040	9065	9065	9072
1	5280000	20/60/100	30	5279880	751992	50	5275200	9079	9079	9086
1	5300000	20/60/100	30	5300040	753336	50	5295360	9093	9093	9100
1	5320000	20/60/100	30	5320200	754680	50	5315520	9107	9107	9114
1	5340000	20/60/100	30	5340000	756000	50	5335680	9121	9121	9127
2	5480000	20/60/100	30	5480040	765336	50	5475360	9218	9218	9225
2	5500000	20/60/100	30	5500200	766680	50	5495520	9232	9232	9239
2	5520000	20/60/100	30	5520000	768000	50	5515680	9246	9246	9252
2	5540000	20/60/100	30	5540160	769344	50	5535840	9260	9260	9266
2	5560000	20/60/100	30	5559960	770664	50	5554560	9273	9273	9280
2	5580000	20/60/100	30	5580120	772008	50	5574720	9287	9287	9294
2	5600000	20/60/100	30	5599920	773328	50	5594880	9301	9301	9308
2	5620000	20/60/100	30	5620080	774672	50	5615040	9315	9315	9322
2	5640000	20/60/100	30	5639880	775992	50	5635200	9329	9329	9336
2	5660000	20/60/100	30	5660040	777336	50	5655360	9343	9343	9350
2	5680000	20/60/100	30	5680200	778680	50	5675520	9357	9357	9364
2	5700000	20/60/100	30	5700000	780000	50	5695680	9371	9371	9377
2	5720000	20/60/100	30	5720160	781344	50	5715840	9385	9385	9391

FIG. 11A



3	5745000	20/60/100	30	5745000	783000	50	5740320	9402	9402	9409
3	5765000	20/60/100	30	5765160	784344	50	5760480	9416	9416	9423
3	5785000	20/60/100	30	5784960	785664	50	5780640	9430	9430	9436
3	5805000	20/60/100	30	5805120	787008	50	5800800	9444	9444	9450
3	5825000	20/60/100	30	5824920	788328	50	5819520	9457	9457	9464
3	5845000	20/60/100	30	5845080	789672	50	5839680	9471	9471	9478
3	5865000	20/60/100	30	5864880	790992	50	5859840	9485	9485	9492
3	5885000	20/60/100	30	5885040	792336	50	5880000	9499	9499	9506
3	5905000	20/60/100	30	5905300	793680	50	5900160	9513	9513	9520
1	5170000	40/80	30	5169900	744660	105	5155680	8996	8996	9016
1	5190000	40/80	30	5190060	746004	105	5175840	9010	9010	9030
1	5210000	40/80	30	5209860	747324	105	5194560	9023	9023	9044
1	5230000	40/80	30	5230020	748668	105	5214720	9037	9037	9058
1	5250000	40/80	30	5250000	750000	106	5234880	9051	9051	9072
1	5270000	40/80	30	5269980	751332	105	5255040	9065	9065	9086
1	5290000	40/80	30	5290140	752676	105	5275200	9079	9079	9100
1	5310000	40/80	30	5309940	753996	105	5295360	9093	9093	9113
1	5330000	40/80	30	5330100	755340	105	5315520	9107	9107	9127
2	5490000	40/80	30	5489940	765996	105	5475360	9218	9218	9238
2	5510000	40/80	30	5510100	767340	105	5495520	9232	9232	9252
2	5530000	40/80	30	5529900	768660	105	5515680	9246	9246	9266
2	5550000	40/80	30	5550060	770004	105	5535840	9260	9260	9280
2	5570000	40/80	30	5569860	771324	105	5554560	9273	9273	9294
2	5590000	40/80	30	5590020	772668	105	5574720	9287	9287	9308
2	5610000	40/80	30	5610000	774000	106	5594880	9301	9301	9322
2	5630000	40/80	30	5629980	775332	105	5615040	9315	9315	9336
2	5650000	40/80	30	5650140	776676	105	5635200	9329	9329	9350

FIG. 11B

1100



2	5670000	40/80	30	5669940	777996	105	5655360	9343	9343	9363
2	5690000	40/80	30	5690100	779340	105	5675520	9357	9357	9377
2	5710000	40/80	30	5709900	780660	105	5695680	9371	9371	9391
3	5755000	40/80	30	5754900	783660	105	5740320	9402	9402	9422
3	5775000	40/80	30	5775060	785004	105	5760480	9416	9416	9436
3	5795000	40/80	30	5794860	786324	105	5780640	9430	9430	9450
3	5815000	40/80	30	5815020	787668	105	5800800	9444	9444	9464
3	5835000	40/80	30	5835000	789000	106	5819520	9457	9457	9478
3	5855000	40/80	30	5854980	790332	105	5839680	9471	9471	9492
3	5875000	40/80	30	5875140	791676	105	5859840	9485	9485	9506
3	5895000	40/80	30	5894940	792996	105	5880000	9499	9499	9520

FIG. 11C

1200

Table 13

UNII-Band	LTE Chn Raster [kHz]	BW [MHz]	Data SCS [kHz]	NR Chn Raster [kHz]	NR-ARFCN (N _{REF})	N_PRB	SS Raster [kHz]	GSCN	Min GSCN	Max GSCN
1	5160000	20/60/100	30	5160000	744000	50	5155680	8996	8996	9002
1	5180000	20/60/100	30	5180160	745344	50	5175840	9010	9010	9016
1	5200000	20/60/100	30	5199960	746664	50	5194560	9023	9023	9030
1	5220000	20/60/100	30	5220120	748008	50	5214720	9037	9037	9044
1	5240000	20/60/100	30	5239920	749328	50	5234880	9051	9051	9058
1	5260000	20/60/100	30	5260080	750672	50	5255040	9065	9065	9072
1	5280000	20/60/100	30	5279880	751992	50	5275200	9079	9079	9086
1	5300000	20/60/100	30	5300040	753336	50	5295360	9093	9093	9100
1	5320000	20/60/100	30	5319840	754656	50	5315520	9107	9107	9113
1	5340000	20/60/100	30	5340000	756000	50	5335680	9121	9121	9127
2	5480000	20/60/100	30	5480040	765336	50	5475360	9218	9218	9225
2	5500000	20/60/100	30	5499840	766656	50	5495520	9232	9232	9238
2	5520000	20/60/100	30	5520000	768000	50	5515680	9246	9246	9252
2	5540000	20/60/100	30	5540160	769344	50	5535840	9260	9260	9266
2	5560000	20/60/100	30	5559960	770664	50	5554560	9273	9273	9280
2	5580000	20/60/100	30	5580120	772008	50	5574720	9287	9287	9294
2	5600000	20/60/100	30	5599920	773328	50	5594880	9301	9301	9308
2	5620000	20/60/100	30	5620080	774672	50	5615040	9315	9315	9322
2	5640000	20/60/100	30	5639880	775992	50	5635200	9329	9329	9336
2	5660000	20/60/100	30	5660040	777336	50	5655360	9343	9343	9350
2	5680000	20/60/100	30	5679840	778656	50	5675520	9357	9357	9363
2	5700000	20/60/100	30	5700000	780000	50	5695680	9371	9371	9377
2	5720000	20/60/100	30	5720160	781344	50	5715840	9385	9385	9391

FIG. 12A

1200

3	5745000	20/60/100	30	5745000	783000	50	5740320	9402	9402	9409
3	5765000	20/60/100	30	5765160	784344	50	5760480	9416	9416	9423
3	5785000	20/60/100	30	5784960	785664	50	5780640	9430	9430	9436
3	5805000	20/60/100	30	5805120	787008	50	5800800	9444	9444	9450
3	5825000	20/60/100	30	5824920	788328	50	5819520	9457	9457	9464
3	5845000	20/60/100	30	5845080	789672	50	5839680	9471	9471	9478
3	5865000	20/60/100	30	5864880	790992	50	5859840	9485	9485	9492
3	5885000	20/60/100	30	5885040	792336	50	5880000	9499	9499	9506
3	5905000	20/60/100	30	5904840	793656	50	5900160	9513	9513	9520
1	5170000	40/80	30	5169900	744660	105	5155680	8996	8996	9016
1	5190000	40/80	30	5190060	746004	105	5175840	9010	9010	9030
1	5210000	40/80	30	5209860	747324	105	5194560	9023	9023	9044
1	5230000	40/80	30	5230020	748668	105	5214720	9037	9037	9058
1	5250000	40/80	30	5250000	750000	106	5234880	9051	9051	9072
1	5270000	40/80	30	5269980	751332	105	5255040	9065	9065	9086
1	5290000	40/80	30	5290140	752676	105	5275200	9079	9079	9100
1	5310000	40/80	30	5309940	753996	105	5295360	9093	9093	9113
1	5330000	40/80	30	5330100	755340	105	5315520	9107	9107	9127
2	5490000	40/80	30	5489940	765996	105	5475360	9218	9218	9238
2	5510000	40/80	30	5510100	767340	105	5495520	9232	9232	9252
2	5530000	40/80	30	5529900	768660	105	5515680	9246	9246	9266
2	5550000	40/80	30	5550060	770004	105	5535840	9260	9260	9280
2	5570000	40/80	30	5569860	771324	105	5554560	9273	9273	9294
2	5590000	40/80	30	5590020	772668	105	5574720	9287	9287	9308
2	5610000	40/80	30	5610000	774000	106	5594880	9301	9301	9322
2	5630000	40/80	30	5629980	775332	105	5615040	9315	9315	9336
2	5650000	40/80	30	5650140	776676	105	5635200	9329	9329	9350

FIG. 12B

1200

2	5670000	40/80	30	5669940	777996	105	5655360	9343	9343	9363
2	5690000	40/80	30	5690100	779340	105	5675520	9357	9357	9377
2	5710000	40/80	30	5709900	780660	105	5695680	9371	9371	9391
3	5755000	40/80	30	5754900	783660	105	5740320	9402	9402	9422
3	5775000	40/80	30	5775060	785004	105	5760480	9416	9416	9436
3	5795000	40/80	30	5794860	786324	105	5780640	9430	9430	9450
3	5815000	40/80	30	5815020	787668	105	5800800	9444	9444	9464
3	5835000	40/80	30	5835000	789000	106	5819520	9457	9457	9478
3	5855000	40/80	30	5854980	790332	105	5839680	9471	9471	9492
3	5875000	40/80	30	5875140	791676	105	5859840	9485	9485	9506
3	5895000	40/80	30	5894940	792996	105	5880000	9499	9499	9520

FIG. 12C

1300

Table 14

UNII-Band	LTE Chn Raster [kHz]	BW [MHz]	Data SCS [kHz]	NR Chn Raster [kHz]	NR-ARFCN (N _{REF})	N _{PRB}	SS Raster [kHz]	GSCN	Min GSCN	Max GSCN
1	5160000	20/60/100	15	5160000	744000	104	5154240	8995	8995	9003
1	5180000	20/60/100	15	5180160	745344	104	5174400	9009	9009	9017
1	5200000	20/60/100	15	5199960	746664	104	5194560	9023	9023	9030
1	5220000	20/60/100	15	5220120	748008	104	5214720	9037	9037	9044
1	5240000	20/60/100	15	5239920	749328	104	5234880	9051	9051	9058
1	5260000	20/60/100	15	5260080	750672	104	5255040	9065	9065	9072
1	5280000	20/60/100	15	5279880	751992	104	5275200	9079	9079	9086
1	5300000	20/60/100	15	5300040	753336	104	5295360	9093	9093	9100
1	5320000	20/60/100	15	5319840	754656	104	5314080	9106	9106	9114
1	5340000	20/60/100	15	5340000	756000	104	5334240	9120	9120	9128
2	5480000	20/60/100	15	5480040	765336	104	5475360	9218	9218	9225
2	5500000	20/60/100	15	5499840	766656	104	5494080	9231	9231	9239
2	5520000	20/60/100	15	5520000	768000	104	5514240	9245	9245	9253
2	5540000	20/60/100	15	5540160	769344	104	5534400	9259	9259	9267
2	5560000	20/60/100	15	5559960	770664	104	5554560	9273	9273	9280
2	5580000	20/60/100	15	5580120	772008	104	5574720	9287	9287	9294
2	5600000	20/60/100	15	5599920	773328	104	5594880	9301	9301	9308
2	5620000	20/60/100	15	5620080	774672	104	5615040	9315	9315	9322
2	5640000	20/60/100	15	5639880	775992	104	5635200	9329	9329	9336
2	5660000	20/60/100	15	5660040	777336	104	5655360	9343	9343	9350
2	5680000	20/60/100	15	5679840	778656	104	5674080	9356	9356	9364
2	5700000	20/60/100	15	5700000	780000	104	5694240	9370	9370	9378
2	5720000	20/60/100	15	5720160	781344	104	5714400	9384	9384	9392

FIG. 13A

1300

3	5745000	20/60/100	15	5745000	783000	104	5740320	9402	9402	9409
3	5765000	20/60/100	15	5765160	784344	104	5760480	9416	9416	9423
3	5785000	20/60/100	15	5784960	785664	104	5779200	9429	9429	9437
3	5805000	20/60/100	15	5805120	787008	104	5799360	9443	9443	9451
3	5825000	20/60/100	15	5824920	788328	104	5819520	9457	9457	9464
3	5845000	20/60/100	15	5845080	789672	104	5839680	9471	9471	9478
3	5865000	20/60/100	15	5864880	790992	104	5859840	9485	9485	9492
3	5885000	20/60/100	15	5885040	792336	104	5880000	9499	9499	9506
3	5905000	20/60/100	15	5904840	793656	104	5900160	9513	9513	9520
1	5170000	40/80	15	5169900	744660	214	5154240	8995	8995	9016
1	5190000	40/80	15	5190060	746004	214	5174400	9009	9009	9030
1	5210000	40/80	15	5209860	747324	214	5194560	9023	9023	9044
1	5230000	40/80	15	5230020	748668	214	5214720	9037	9037	9058
1	5250000	40/80	15	5250000	750000	216	5234880	9051	9051	9072
1	5270000	40/80	15	5269980	751332	214	5255040	9065	9065	9086
1	5290000	40/80	15	5290140	752676	214	5275200	9079	9079	9100
1	5310000	40/80	15	5309940	753996	214	5295360	9093	9093	9114
1	5330000	40/80	15	5330100	755340	214	5315520	9107	9107	9128
2	5490000	40/80	15	5489940	765996	214	5475360	9218	9218	9239
2	5510000	40/80	15	5510100	767340	214	5495520	9232	9232	9253
2	5530000	40/80	15	5529900	768660	214	5514240	9245	9245	9266
2	5550000	40/80	15	5550060	770004	214	5534400	9259	9259	9280
2	5570000	40/80	15	5569860	771324	214	5554560	9273	9273	9294
2	5590000	40/80	15	5590020	772668	214	5574720	9287	9287	9308
2	5610000	40/80	15	5610000	774000	216	5594880	9301	9301	9322
2	5630000	40/80	15	5629980	775332	214	5615040	9315	9315	9336
2	5650000	40/80	15	5650140	776676	214	5635200	9329	9329	9350

FIG. 13B

1300

2	5670000	40/80	15	5669940	777996	214	5655360	9343	9343	9364
2	5690000	40/80	15	5690100	779340	214	5675520	9357	9357	9378
2	5710000	40/80	15	5709900	780660	214	5694240	9370	9370	9391
3	5755000	40/80	15	5754900	783660	214	5740320	9402	9402	9423
3	5775000	40/80	15	5775060	785004	214	5760480	9416	9416	9437
3	5795000	40/80	15	5794860	786324	214	5779200	9429	9429	9450
3	5815000	40/80	15	5815020	787668	214	5799360	9443	9443	9464
3	5835000	40/80	15	5835000	789000	216	5819520	9457	9457	9478
3	5855000	40/80	15	5854980	790332	214	5839680	9471	9471	9492
3	5875000	40/80	15	5875140	791676	214	5859840	9485	9485	9506
3	5895000	40/80	15	5894940	792996	214	5880000	9499	9499	9520

FIG. 13C

Table 15

UNIL-Band	LTE Chn Raster [kHz]	BW [MHz]	Data SCS [kHz]	NR Chn Raster [kHz]	NR-ARFCN (N _{REF})	N_PRB	SS Raster [kHz]	GSCN	Min GSCN	Max GSCN
1	5160000	20/60/100	30	5160000	744000	50	5155680	8996	8996	9002
1	5180000	20/60/100	30	5180160	745344	50	5175840	9010	9010	9016
1	5200000	20/60/100	30	5199960	746664	50	5194560	9023	9023	9030
1	5220000	20/60/100	30	5220120	748008	50	5214720	9037	9037	9044
1	5240000	20/60/100	30	5239920	749328	50	5234880	9051	9051	9058
1	5260000	20/60/100	30	5260080	750672	50	5255040	9065	9065	9072
1	5280000	20/60/100	30	5279880	751992	50	5275200	9079	9079	9086
1	5300000	20/60/100	30	5300040	753336	50	5295360	9093	9093	9100
1	5320000	20/60/100	30	5320020	754668	51	5315520	9107	9107	9114
1	5340000	20/60/100	30	5340000	756000	50	5335680	9121	9121	9127
2	5480000	20/60/100	30	5480040	765336	50	5475360	9218	9218	9225
2	5500000	20/60/100	30	5500020	766668	51	5495520	9232	9232	9239
2	5520000	20/60/100	30	5520000	768000	50	5515680	9246	9246	9252
2	5540000	20/60/100	30	5540160	769344	50	5535840	9260	9260	9266
2	5560000	20/60/100	30	5559960	770664	50	5554560	9273	9273	9280
2	5580000	20/60/100	30	5580120	772008	50	5574720	9287	9287	9294
2	5600000	20/60/100	30	5599920	773328	50	5594880	9301	9301	9308
2	5620000	20/60/100	30	5620080	774672	50	5615040	9315	9315	9322
2	5640000	20/60/100	30	5639880	775992	50	5635200	9329	9329	9336
2	5660000	20/60/100	30	5660040	777336	50	5655360	9343	9343	9350
2	5680000	20/60/100	30	5680020	778668	51	5675520	9357	9357	9364
2	5700000	20/60/100	30	5700000	780000	50	5695680	9371	9371	9377
2	5720000	20/60/100	30	5720160	781344	50	5715840	9385	9385	9391

1400

FIG. 14A

1400

3	5745000	20/60/100	30	5745000	783000	50	5740320	9402	9402	9409
3	5765000	20/60/100	30	5765160	784344	50	5760480	9416	9416	9423
3	5785000	20/60/100	30	5784960	785664	50	5780640	9430	9430	9436
3	5805000	20/60/100	30	5805120	787008	50	5800800	9444	9444	9450
3	5825000	20/60/100	30	5824920	788328	50	5819520	9457	9457	9464
3	5845000	20/60/100	30	5845080	789672	50	5839680	9471	9471	9478
3	5865000	20/60/100	30	5864880	790992	50	5859840	9485	9485	9492
3	5885000	20/60/100	30	5885040	792336	50	5880000	9499	9499	9506
3	5905000	20/60/100	30	5905020	793668	51	5900160	9513	9513	9520
1	5170000	40/80	30	5169900	744660	105	5155680	8996	8996	9016
1	5190000	40/80	30	5190060	746004	105	5175840	9010	9010	9030
1	5210000	40/80	30	5209860	747324	105	5194560	9023	9023	9044
1	5230000	40/80	30	5230020	748668	105	5214720	9037	9037	9058
1	5250000	40/80	30	5250000	750000	106	5234880	9051	9051	9072
1	5270000	40/80	30	5269980	751332	105	5255040	9065	9065	9086
1	5290000	40/80	30	5290140	752676	105	5275200	9079	9079	9100
1	5310000	40/80	30	5309940	753996	105	5295360	9093	9093	9113
1	5330000	40/80	30	5330100	755340	105	5315520	9107	9107	9127
2	5490000	40/80	30	5489940	765996	105	5475360	9218	9218	9238
2	5510000	40/80	30	5510100	767340	105	5495520	9232	9232	9252
2	5530000	40/80	30	5529900	768660	105	5515680	9246	9246	9266
2	5550000	40/80	30	5550060	770004	105	5535840	9260	9260	9280
2	5570000	40/80	30	5569860	771324	105	5554560	9273	9273	9294
2	5590000	40/80	30	5590020	772668	105	5574720	9287	9287	9308
2	5610000	40/80	30	5610000	774000	106	5594880	9301	9301	9322
2	5630000	40/80	30	5629980	775332	105	5615040	9315	9315	9336
2	5650000	40/80	30	5650140	776676	105	5635200	9329	9329	9350

FIG. 14B

1400
↘

2	5670000	40/80	30	5669940	777996	105	5655360	9343	9343	9363
2	5690000	40/80	30	5690100	779340	105	5675520	9357	9357	9377
2	5710000	40/80	30	5709900	780660	105	5695680	9371	9371	9391
3	5755000	40/80	30	5754900	783660	105	5740320	9402	9402	9422
3	5775000	40/80	30	5775060	785004	105	5760480	9416	9416	9436
3	5795000	40/80	30	5794860	786324	105	5780640	9430	9430	9450
3	5815000	40/80	30	5815020	787668	105	5800800	9444	9444	9464
3	5835000	40/80	30	5835000	789000	106	5819520	9457	9457	9478
3	5855000	40/80	30	5854980	790332	105	5839680	9471	9471	9492
3	5875000	40/80	30	5875140	791676	105	5859840	9485	9485	9506
3	5895000	40/80	30	5894940	792996	105	5880000	9499	9499	9520

FIG. 14C

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CHANNEL RASTER AND SYNCHRONIZATION SIGNAL RASTER FOR NR UNLICENSED SPECTRUM

CROSS-REFERENCE TO RELATED APPLICATION(S)

This application is a national stage filing under 35 U.S.C. § 371 of International Patent Application No. PCT/US2020/032736 filed May 13, 2020, which claims the benefit of U.S. Provisional Application No. 62/847,770 filed May 14, 2019, entitled “CHANNEL RASTER AND SYNCHRONIZATION SIGNAL RASTER FOR NR UNLICENSED SPECTRUM,” each of which is hereby incorporated by reference herein in its entirety.

TECHNICAL FIELD

This application relates generally to wireless communication systems, and more specifically to channel raster and synchronization signal raster use for New Radio unlicensed spectrum.

BACKGROUND

Wireless mobile communication technology uses various standards and protocols to transmit data between a base station and a wireless mobile device. Wireless communication system standards and protocols can include the 3rd Generation Partnership Project (3GPP) long term evolution (LTE) (e.g., 4G) or new radio (NR) (e.g., 5G); the Institute of Electrical and Electronics Engineers (IEEE) 802.16 standard, which is commonly known to industry groups as worldwide interoperability for microwave access (WiMAX); and the IEEE 802.11 standard for wireless local area networks (WLAN), which is commonly known to industry groups as Wi-Fi. In 3GPP radio access networks (RANs) in LTE systems, the base station can include a RAN Node such as an Evolved Universal Terrestrial Radio Access Network (E-UTRAN) Node B (also commonly denoted as evolved Node B, enhanced Node B, eNodeB, or eNB) and/or Radio Network Controller (RNC) in an E-UTRAN, which communicate with a wireless communication device, known as user equipment (UE). In fifth generation (5G) wireless RANs, RAN Nodes can include a 5G Node, NR node (also referred to as a next generation Node B or g Node B (gNB)).

RANs use a radio access technology (RAT) to communicate between the RAN Node and UE. RANs can include global system for mobile communications (GSM), enhanced data rates for GSM evolution (EDGE) RAN (GERAN), Universal Terrestrial Radio Access Network (UTRAN), and/or E-UTRAN, which provide access to communication services through a core network. Each of the RANs operates according to a specific 3GPP RAT. For example, the GERAN implements GSM and/or EDGE RAT, the UTRAN implements universal mobile telecommunication system (UMTS) RAT or other 3GPP RAT, the E-UTRAN implements LTE RAT, and NG-RAN implements 5G RAT. In certain deployments, the E-UTRAN may also implement 5G RAT.

Frequency bands for 5G NR may be separated into two different frequency ranges. Frequency Range 1 (FR1) includes sub-6 GHz frequency bands, some of which are bands that may be used by previous standards, but may potentially be extended to cover potential new spectrum offerings from 410 MHz to 7125 MHz. Frequency Range 2 (FR2) includes frequency bands from 24.25 GHz to 52.6

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GHz. Bands in the millimeter wave (mmWave) range of FR2 have shorter range but higher available bandwidth than bands in the FR1. Skilled persons will recognize these frequency ranges, which are provided by way of example, may change from time to time or from region to region.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

The patent or application file contains at least one drawing executed in color. Copies of this patent or patent application publication with color drawing(s) will be provided by the Office upon request and payment of the necessary fee.

To easily identify the discussion of any particular element or act, the most significant digit or digits in a reference number refer to the figure number in which that element is first introduced.

FIG. 1 illustrates a diagram of two adjacent New Radio (NR) cells operating with 15 kHz subcarrier spacing (SCS) that are placed in the center of the 20 MHz band.

FIG. 2 illustrates a diagram of two adjacent New Radio (NR) cells operating with a 30 kHz subcarrier spacing (SCS) that are placed in the center of the 20 MHz band.

FIG. 3 illustrates a diagram of a pair of New Radio (NR) channels having channel raster positions and synchronization signal and physical broadcast channel (SSB) raster positions calculated using methods disclosed herein.

FIG. 4 illustrates a method of determining characteristics of an New Radio (NR) channel according to embodiments disclosed herein.

FIG. 5 illustrates an example service based architecture in accordance with certain embodiments.

FIG. 6 illustrates a UE in accordance with one embodiment.

FIG. 7 illustrates a network node in accordance with one embodiment.

FIG. 8 illustrates components in accordance with one embodiment.

FIGS. 9A through 9C illustrate a Table 8 for one example of channel raster entries for 30 KHz, according to embodiments discussed herein.

FIGS. 10A through 10C illustrate a Table 9 for one example of SSB raster entries for 30 KHz, according to embodiments discussed herein.

FIGS. 11A through 11C illustrate a Table 12 that shows NR channel raster entries that could be applicable for both 30 KHz data subcarrier operation, according to embodiments discussed herein.

FIGS. 12A through 12C illustrate a Table 13 that shows NR channel raster entries that could be applicable for both 30 kHz and 15 KHz data subcarrier operation, according to embodiments discussed herein.

FIGS. 13A through 13C illustrate a Table 14 that shows NR channel raster entries that could be applicable for both 30 kHz and 15 KHz data subcarrier operation, according to embodiments discussed herein.

FIGS. 14A through 14C illustrate a Table 15 for down selection, according to embodiments discussed herein.

DETAILED DESCRIPTION

The following detailed description refers to the accompanying drawings. The same reference numbers may be used in different drawings to identify the same or similar elements. In the following description, for purposes of explanation and not limitation, specific details are set forth such as particular structures, architectures, interfaces, techniques,

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etc. in order to provide a thorough understanding of the various aspects of various embodiments. However, it will be apparent to those skilled in the art having the benefit of the present disclosure that the various aspects of the various embodiments may be practiced in other examples that depart from these specific details. In certain instances, descriptions of well-known devices, circuits, and methods are omitted so as not to obscure the description of the various embodiments with unnecessary detail. For the purposes of the present document, the phrase "A or B" means (A), (B), or (A and B).

LTE channel raster are center frequency positions in which wireless system can deploy a cell. These are the center frequency of the carrier and may correspond to the DC subcarrier of the cell. In unlicensed bands, LTE channel raster are in units of non-overlapping 20 MHz, with two non-overlapping 20 MHz usually adjacent to each other (without any frequency gap between). More specifically, the LTE channel raster are on {5160, 5180, 5200, 5220, 5240, 5260, 5280, 5300, 5320, 5340} MHz for the UNII-1 band, {5480, 5500, 5520, 5540, 5560, 5580, 5600, 5620, 5640, 5660, 5680, 5700, 5720} MHz for the UNII-2 band, and {5745, 5765, 5785, 5805, 5825, 5845, 5865, 5885, 5905} MHz for the UNII-3 band.

Radio Frequency (RF) reference frequencies are designated by an NR Absolute Radio Frequency Channel Number (NR-ARFCN) in the range [0 . . . 3279165] on the global frequency raster (i.e., the NR channel raster). The relation between the NR-ARFCN and the RF reference frequency F_{REF} in MHz is given by the following equation, where $F_{REF-Offs}$ and $N_{REF-Offs}$ are given in following table and N_{REF} is the NR-ARFCN:

$$F_{REF} = F_{REF-Offs} + \Delta F_{Global}(N_{REF} - N_{REF-Offs})$$

TABLE 1

NR-ARFCN Parameters for the Global Frequency Raster				
Frequency range (MHz)	ΔF_{Global} (kHz)	$F_{REF-Offs}$ (MHz)	$N_{REF-Offs}$	Range of N_{REF}
0-3000	5	0	0	0-599999
3000-24250	15	3000	600000	600000-2016666
24250-100000	60	24250.08	2016667	2016667-3279165

The channel raster defines a subset of RF reference frequencies that can be used to identify the RF channel position in the uplink and downlink. The RF reference frequency for an RF channel maps to a resource element on the carrier. The mapping between the RF reference frequency on the channel raster and the corresponding resource element is given in Table 2 and can be used to identify the RF channel position.

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TABLE 2

Channel Raster to Resource Element Mapping		
	$N_{RB \bmod 2} = 0$	$N_{RB \bmod 2} = 1$
Resource element index k	0	6
Physical resource block number n_{PRB}	$n_{PRB} = \lfloor \frac{N_{RB}}{2} \rfloor$	$n_{PRB} = \lfloor \frac{N_{RB}}{2} \rfloor$

The mapping depends on the total number of resource blocks (RBs) that are allocated in the channel and applies to both uplink (UL) and downlink (DL). The mapping must apply to at least one numerology supported by the base station (BS). Additionally, k is the subcarrier index (or resource element index in the frequency domain), n_{PRB} is the physical resource block (PRB) index, and N_{RB} (also denoted herein as N_{RB} or N_{RB}) is the number of PRBs in the cell.

The synchronization raster indicates the frequency positions of the synchronization block that can be used by the UE for system acquisition when explicit signaling of the synchronization block position is not present. A global synchronization raster is defined for all frequencies. The frequency position of the Synchronization Signal (SS) block is defined as SS_{REF} with a corresponding Global Synchronization Channel Number (GSCN). The parameters defining the SS_{REF} and GSCN for all the frequency ranges are in Table 3. The synchronization raster and the subcarrier spacing of the synchronization block are defined separately for each band.

TABLE 3

GSCN Parameter for Global Frequency Raster			
Frequency range	SS block frequency position SS_{REF}	GSCN	Range of GSCN
0-3000 MHz	$N * 1200 \text{ kHz} + M * 50 \text{ kHz}$, $N = 1:2499, M \in \{1, 3, 5\}$ (Note)	$3N + (M-3)/2$	2-7498
3000-24250 MHz	$3000 \text{ MHz} + N * 1.44 \text{ MHz}$ $N = 0:14756$	$7499 + N$	7499-22255
24250-100000 MHz	$24250.08 \text{ MHz} + N * 17.28 \text{ MHz}$ $N = 0:4383$	$22256 + N$	22256-26639

NOTE:

The default value for operating bands with SCS spaced channel raster is $M = 3$.

The mapping between the synchronization raster and the corresponding resource element of the SS block is given in Table 4. The mapping depends on the total number of RBs that are allocated in the channel and applies to both UL and DL.

TABLE 4

Synchronization Raster to SS block Resource Element Mapping	
Resource element index k of the SS block	0
Physical resource block number n_{PRB} of the SS block	$n_{PRB} = 10$

Due to the granularity of the NR channel raster frequency locations, it is not possible, without modification, to perfectly align them with LTE channel raster for the same unlicensed band. However, due to coexistence between Wi-Fi systems and LTE Unlicensed systems that may be operating in the same band, NR unlicensed systems may find it beneficial to use similar if not identical channel raster entries.

It may be possible to change the NR channel raster positions for the unlicensed band such that they are identical to the LTE channel raster positions. However, in such deployments (with the same LTE channel raster positions) due to required guard bands for NR cells, two adjacent cells cannot be placed on the same subcarrier grid nor same PRB grids. This can be easily seen in illustrations in FIG. 1 and FIG. 2. FIG. 1 illustrates a diagram 100 of two adjacent NR cells operating with a 15 kHz subcarrier spacing that are placed in the center of the 20 MHz band. In such a case, the gap between two occupied frequencies is not divisible by the operated subcarrier spacing, which is 15 kHz.

An analogous situation is shown in FIG. 2. FIG. 2 illustrates a diagram 200 of two adjacent NR cells operating with a 30 kHz subcarrier spacing that are placed in the center of the 20 MHz band. In this case, the subcarrier grid (which is the regular pattern and period of center of subcarrier positions) between the two cells would not be aligned and therefore, the transceiver would may not be able to perform a single inverse FFT and FFT operation to process signals from two cells simultaneously. (Note that in FIG. 1 and FIG. 2, the “center” of the 20 MHz band does not necessary mean exactly in the center so as to have same guard bandwidths at either edges of the bandwidth. The center of the NR carrier will be shifted by 1/2 subcarrier due to the fact that there is always even number of subcarriers. Accordingly, to position the channel raster position in the center of subcarrier, the entire bandwidth will be shifted by 1/2 subcarrier.)

Accordingly, the selection of the NR channel raster positions becomes an important factor in allowing support of subcarrier and PRB grid alignment, in order to enable efficient transceiver design for multiple component carrier operations (i.e. multiple cell operations).

In addition, the process of selecting NR channel raster positions also needs to factor into account synchronization signal and physical broadcast channel (referred to herein as SSB and/or SS Block) raster entries (also referred to herein as SSB raster entries, SSB raster positions, SSB raster values, SSB raster points, and/or SS rasters). SSB raster entries are the center of the SSB that needs to be positioned within the cell. The subcarrier grid of the SSB also needs to be aligned with subcarrier grid of the rest of the cell to insure orthogonal transmission of SSB and rest of the system, when same subcarrier spacing is used for both. Therefore, the combination of the SSB raster position and NR channel raster position should be selected such that the operating cell

fits within the 20 MHz LTE channels (to enable efficient coexistence), allow subcarrier and PRB grid alignment between cells, and allow subcarrier (and possibly PRB grid) alignment between SSB and rest of the signals and channels of the cell.

This process is not trivial and requires significant engineering work. This disclosure address how the NR channel and SSB raster entries can be chosen, and proposed channel and SSB raster entries that provide numerous benefits to transceiver design.

There are no known solutions that address PRB grid alignment between cells, PRB grid alignment between SSB and rest of the signal/channel of the cell, and alignment of 20 MHz channel deployments between LTE, NR, and Wi-Fi systems.

The proposed NR channel and SSB raster entries would allow cells deployed in carrier aggregation to be implemented using a single FFT (and inverse FFT) in the transceivers. Additionally, by also supporting PRB grid alignment between cells and PRB grid alignment between SSB and rest of the signals in the channel, it would allow efficient use of spectrum and simplify transceiver implementation even further.

The NR channel raster is given as $F_{REF} = F_{REF-Offs} + \Delta F_{Global} (N_{REF} - N_{REF-Offs})$, where the $\Delta F_{Global} = 15$ kHz, $F_{REF-Offs} = 3000$ MHz, and $N_{REF-Offs} = 600000$.

The N_{REF} for a system operating with 30 kHz is selected among the set of {744000, 745344, 746664, 748008, 749328, 750672, 751992, 753336, 754656, 754668, 754680, 756000, 765336, 766656, 766668, 766680, 768000, 769344, 770664, 772008, 773328, 774672, 775992, 777336, 778656, 778668, 778680, 780000, 781344, 783000, 784344, 785664, 787008, 788328, 789672, 790992, 792336, 793656, 793668, 793680, 744660, 746004, 747324, 748668, 749988, 750000, 750012, 751332, 752676, 753996, 755340, 765996, 767340, 768660, 770004, 771324, 772668, 773988, 774000, 774012, 775332, 776676, 777996, 779340, 780660, 783660, 785004, 786324, 787668, 788988, 789000, 789012, 790332, 791676, 792996}.

The N_{REF} for system operating with 15 kHz is selected among set of {744000, 744006, 745344, 746664, 746670, 748008, 749328, 749334, 750672, 751992, 51998, 753336, 754656, 754662, 756000, 756006, 765336, 766656, 766662, 768000, 768006, 69344, 770664, 770670, 772008, 773328, 773334, 774672, 775992, 775998, 777336, 78656, 778662, 780000, 780006, 781344, 783000, 783006, 784344, 785664, 785670, 787008, 788328, 788334, 789672, 790992, 790998, 792336, 793656, 793662, 744660, 744666, 746004, 747324, 47330, 748668, 749988, 749994, 750000, 750012, 751332, 751338, 752676, 753996, 754002, 755340, 765996, 766002, 767340, 768660, 768666, 770004, 771324, 771330, 772668, 773988, 773994, 774000, 774012, 775332, 775338, 776676, 777996, 778002, 779340, 780660, 780666, 783660, 783666, 785004, 786324, 786330, 787668, 788988, 788994, 789000, 789012, 790332, 790338, 791676, 792996, 793002}.

The SSB raster is given by “3000 MHz+N*1.44 MHz”, where N is a value from range 0 to 14756 and GSCN is given as “7499+N”. The GSCN is selected as K+a value from set {8996, 9010, 9023, 9037, 9051, 9065, 9079, 9093, 9107, 9121, 9218, 9232, 9232, 9232, 9246, 9260, 9273, 9287, 9301, 9315, 9329, 9343, 9357, 9357, 9357, 9371, 9385, 9402, 9416, 9430, 9444, 9457, 9471, 9485, 9499, 9513, 9513, 9513, 8996, 9010, 9023, 9037, 9051, 9065, 9079, 9093, 9107, 9218, 9232, 9246, 9260, 9273, 9287}, where K=0 . . . 6.

This disclosure allows simplified transceiver implementation that would save power consumption and reduce initial

access acquisition (e.g., the time it takes to find suitable cell(s)) latency for NR in an unlicensed spectrum.

Possible channel and SSB raster entries that provide benefits to transceiver implementation may be computed as follows:

Calculate NR-ARFCN values between 5-6 GHz (Unlicensed Spectrum) using the formula $F_{REF} = F_{REF-Offs} + \Delta F_{Global} (N_{REF} - N_{REF-Offs})$.

Calculate GSCN values on a 1.44 MHz (or a multiple of 1.44 MHz) grid using the formula, $3000 \text{ MHz} + N * 1.44 \text{ MHz}$, where $N=0:14756$. Note: The NR-ARFCN values are placed on a 15/30/60 kHz grid. In LTE, the channels were placed on a 100 kHz grid. The NR channel center frequency values should be as close to the LTE channel center frequencies as possible.

Based on subcarrier spacing and channel bandwidth, the maximum transmission bandwidth is determined. The following table may be used for this purpose.

TABLE 5

Maximum transmission bandwidth configuration N_{RB}												
SCS (kHz)	5 N_{RB}	10 N_{RB}	15 N_{RB}	20 N_{RB}	25 N_{RB}	30 N_{RB}	40 N_{RB}	50 N_{RB}	60 N_{RB}	80 N_{RB}	90 N_{RB}	100 N_{RB}
15	25	52	79	106	133	160	216	270	N/A	N/A	N/A	N/A
30	11	24	38	51	65	78	106	133	162	217	245	273
60	N/A	11	18	24	31	38	51	65	79	107	121	135

The following table is used to determine the placement of the channel raster based on the number of PRBs.

TABLE 6

Channel Raster to Resource Element Mapping		
	$N_{RB} \bmod 2 = 0$	$N_{RB} \bmod 2 = 1$
Resource element index k	0	6
Physical resource block number n_{PRB}	$n_{PRB} = \lfloor \frac{N_{RB}}{2} \rfloor$	$n_{PRB} = \lfloor \frac{N_{RB}}{2} \rfloor$

The edges of the channel and the Occupied Channel BW (OCB) are calculated based on the placement of the channel raster.

The SSB block is 20 PRBs wide and is positioned such that the raster lies on the 0th subcarrier of the 10th PRB. The SS Block must lie within the channel. The SSB raster values lie on a 1.44 MHz grid and the channel raster points lie on a 15/30/60 kHz grid. SSB raster points are selected such that they also coincide with the channel raster grid. Raster points are assumed to lie at the center of the subcarrier.

Guard band values are calculated from the edges of the channel. Minimum guardband requirement must be met.

TABLE 7

Minimum Guardband for Each UE Channel Bandwidth and SCS (kHz)												
SCS (kHz)	5 MHz	10 MHz	15 MHz	20 MHz	25 MHz	30 MHz	40 MHz	50 MHz	60 MHz	80 MHz	90 MHz	100 MHz
15	242.5	312.5	382.5	452.5	522.5	592.5	552.5	692.5	N/A	N/A	N/A	N/A
30	505	665	825	985	1145	1305	1165	1425	1585	1745	1905	2065
60	N/A	1010	1310	1610	1910	2210	1910	2410	2710	3010	3310	3610

Note: Calculation of channel, OCB, and guardbands must account for the 1 subcarrier utilized for Channel raster.

k_{SSB} (also denoted herein as k_{SSB}) is the number of subcarriers between the SSB block edges and the channel edges on both sides of the OCB. Calculate the k_{SSB} values.

The number of PRBs within the channel are calculated by subtracting the guardbands from the OCB.

FIG. 3 illustrates a diagram 300 of a pair of NR channels having channel raster positions and SSB raster positions calculated using methods disclosed herein. For example, the NR channels of FIG. 3 may correspond to calculations made using the process just described.

The steps listed above generate all possible channel raster & SSB raster entries which meet the below four criteria:

First, the SS block must lie within the occupied channel bandwidth.

Second, the PRBs in the SS Block and the Channel must be aligned on the same grid (resulting in $k_{SSB}=0$).

Third, the PRBs in cells in different channels must be aligned on the same PRB grid. This can be checked by making sure the frequency difference between the first subcarriers of the occupied channel bandwidth in different cells are multiple integer of a single PRB bandwidth.

Fourth, minimum guardband requirements must be met. Conditions for Down-Selecting Entries from all Possible Channel Raster & SSB Raster Entries

The possible channel raster and SSB raster entries that may be computed (e.g., as discussed above) can be further down-selected. The additional down-selection allows for a single NR channel entry per 20 MHz for support, which may significantly simplify the initial access procedures and latency involved in searching for a valid SSB.

For the 30 kHz data subcarrier spacing case, an NR channel raster entry point is selected that allows for support for at least 50 PRBs within a 20 MHz LTE channel band and at least 105 PRBs within a 40 MHz channel band. For the 15 kHz data subcarrier spacing case, an NR channel raster entry point is selected that allows support for at least 104 PRBs within a 20 MHz LTE channel band and at least 214 PRBs within 40 MHz channel band. The determination of whether a certain number of PRBs can be utilized for an NR channel raster entry point can be performed by computing the available guard bands to the left and right of the occupied

system bandwidth. The computed guard band must be larger than the minimum guard band requirement specified in TS38.101-1 and 38.104.

Further, NR channel raster entry points are selected that allow alignment of PRB grids between different component carriers. This may be performed by selecting NR channel raster entry points with a specific number of PRBs that have a multiple integer of 12×30 KHz difference between first subcarriers of the occupied system bandwidth. This may also be performed by choosing channel raster entry points that have multiple integer of 12×2 values of N_{REF} .

Further, NR channel raster entry points are selected that allow for PRB grid alignment between SSB PRBs and a common PRB grid. This is equivalent to finding raster entry points that allow the k_{SSB} parameter to be equal to 0.

The conditions regarding alignment of PRB grids between different component carriers and PRB grid alignment between SSB PRBs and a common PRB grid can be simultaneously satisfied if an NR channel raster entry point is selected with a specific number of PRBs that have remainder of 120 kHz when a first subcarrier frequency position of the occupied system bandwidth is divided by 12×30 kHz (or, equivalently, a remainder of N_{REF} divided by 12×2 is 0).

Finally, a set of SSB raster entry points (a range of GSCN values) are found that allow the SSBs to be placed within the occupied system bandwidth when paired with selected NR channel raster entry point with a specific number of PRBs. Down-Selection Process Flow

The following condition(s) and/or alternative(s) are used to down-select the entries from all available channel & SSB raster entries:

First, the PRB's of the channel and SS block must be aligned on the same grid. This requirement is met if the OCB starting position is has the same remainder value when divided by "subcarrier spacing*12".

If the first condition is met, channel raster points can be further down-selected to ensure $k_{SSB}=0$. There are then two alternatives with respect to the number of PRBs: either 1) ensure all channels have same number of PRBs, or 2) select the maximum number of PRBs available, based on SCS. Selecting option 1 aligns the PRBs for 15 kHz and 30 kHz channel spacing using the same channel raster points for 20 MHz and 40 MHz channel bandwidth.

FIG. 4 illustrates a method 400 of determining characteristics of an NR channel according to embodiments disclosed herein. The method 400 includes calculating ARFCN and GSCN values in block 402.

The method 400 further includes selecting a number of PRBs based on a SCS in block 404.

The method 400 further includes determining whether the number of PRBs mod 2 is equal to zero (in other words, whether the number of PRBs is even) in decision block 406. If so the method proceeds to determine that the NR channel raster position lies on an element of a PRB with index $k=0$ in block 408. If not, the method proceeds to determine that the NR channel raster position lies on an element of a PRB with index $k=6$ in block 424.

The method 400 further includes computing NR channel edges and OCB edges based on the NR channel center frequency and the NR channel raster placement in block 410.

The method 400 further includes calculating SS Block edges to ensure that it lies within the NR channel in block 412.

The method 400 further includes ensuring that a minimum guardband is available on both edges of the OCB in block 414.

The method 400 further includes checking if $\text{mod}(\text{OCB start position, SCS} \times 12) = X$ to ensure that the PRBs of OCB of different NR channels are PBR grid aligned in block 416. The method 400 further includes checking if $k_{SSB}=0$ in block 418.

The method 400 may further include one of block 420 and block 422. In block 420, a maximum number of PRBs may be selected per channel. This may result in maximum spectral efficiency. In block 422 a same number of PRBs is selected per NR channel. This may result in alignment of PRBs for 15 kHz and 30 kHz using the same NR channel raster points (20 MHz and 40 MHz).

Example Set of Channel Raster & SSB Raster Entries for 30 kHz

FIGS. 9A through 9C illustrate a Table 8 900 and FIGS. 10A through 10C illustrate a Table 9 1000, where Table 8 900 and Table 9 1000 are one example of channel and SSB raster entries for 30 KHz.

Column LTE Chn Raster [kHz] contain the relevant channel raster entry for LTE, BW column specifies the channel bandwidth that the channel raster entry can be applicable for. In case of 20/60/100 entry, this means that the entry is applicable for 20 MHz, 60 MHz, and 100 MHz. In case of 40/80 entry, this means that entry is applicable for 40 MHz and 80 MHz. NR Chn Raster and NR-ARFCN columns provide the NR channel raster frequency position and its corresponding N_{REF} value. N_{PRB} columns shows the number of PRBs that could be used for the channel. SS Raster and GSCN column shows one example position of SSB frequency position and its corresponding GSCN value. It should be noted that any value of GSCN between value specified by Min GSCN and Max GSCN value can be used for the NR channel raster entry (row). It should be further noted that if GSCN (Min GSCN+K) is used for one of the NR channel raster entry, the same value of K should be used for all channel raster entries specified in the tables.

k_{SSB} column provides the k_{SSB} parameter for the selected SSB raster entry and NR channel raster entry combination. The RB offset (left) and (right) columns provide the number of PRBs that are available to the left and right of the SSB. In the case of a 3 PB Offset left and 27 RB offset right, this means that there are 3 PRB of the lower frequency, followed by SSB (which is 20 PRBs), and followed by 27 PRBs at the higher frequency within the occupied channel bandwidth. In such a case, the Occ. Chn-Start, Occ. Chn-End columns represent the center frequency of the first subcarrier (i.e., the subcarrier with the lowest frequency) of the occupied channel bandwidth and last subcarrier (i.e., the subcarrier with the highest frequency) of the occupied channel bandwidth, respectively.

The Left and Right Guard columns represent the leftover guard bands outside the occupied channel bandwidth. The SSB Start and End columns represent the center frequency of the first subcarrier (i.e., the subcarrier with the lowest frequency) of the SSB and last subcarrier (i.e., the subcarrier with the highest frequency) of the SSB, respectively.

Example Set of Channel Raster & SSB Raster Entries for 15 kHz

Table 10 and Table 11 are one example of channel and SSB raster entries for 15 KHz.

TABLE 10

Entry No.	UNII-Band	LTE Chn Raster [kHz]	BW [MHz]	Data SCS [kHz]	NR Chn Raster [kHz]	NR-ARFCN (N_{REF})	N_PRB	SS Raster [kHz]	GSCN	Min GSCN	Max GSCN
101	1	5160000	20/60/100	15	5160000	744000	104	5154240	8995	8995	9003
102	1	5160000	20/60/100	15	5160090	744006	105	5154240	8995	8995	9003
103	1	5180000	20/60/100	15	5180160	745344	104	5174400	9009	9009	9017
104	1	5200000	20/60/100	15	5199960	746664	104	5194560	9023	9023	9030
105	1	5200000	20/60/100	15	5200050	746670	105	5194560	9023	9023	9030
106	1	5220000	20/60/100	15	5220120	748008	104	5214720	9037	9037	9044
107	1	5240000	20/60/100	15	5239920	749328	104	5234880	9051	9051	9058
108	1	5240000	20/60/100	15	5240010	749334	105	5234880	9051	9051	9058
109	1	5260000	20/60/100	15	5260080	750672	104	5255040	9065	9065	9072
110	1	5280000	20/60/100	15	5279880	751992	104	5275200	9079	9079	9086
111	1	5280000	20/60/100	15	5279970	751998	105	5275200	9079	9079	9086
112	1	5300000	20/60/100	15	5300040	753336	104	5295360	9093	9093	9100
113	1	5320000	20/60/100	15	5319840	754656	104	5314080	9106	9106	9114
114	1	5320000	20/60/100	15	5319930	754662	105	5314080	9106	9106	9114
115	1	5340000	20/60/100	15	5340000	756000	104	5334240	9120	9120	9128
116	1	5340000	20/60/100	15	5340090	756006	105	5334240	9120	9120	9128
117	2	5480000	20/60/100	15	5480040	765336	104	5475360	9218	9218	9225
118	2	5500000	20/60/100	15	5499840	766656	104	5494080	9231	9231	9239
119	2	5500000	20/60/100	15	5499930	766662	105	5494080	9231	9231	9239
120	2	5520000	20/60/100	15	5520000	768000	104	5514240	9245	9245	9253
121	2	5520000	20/60/100	15	5520090	768006	105	5514240	9245	9245	9253
122	2	5540000	20/60/100	15	5540160	769344	104	5534400	9259	9259	9267
123	2	5560000	20/60/100	15	5559960	770664	104	5554560	9273	9273	9280
124	2	5560000	20/60/100	15	5560050	770670	105	5554560	9273	9273	9280
125	2	5580000	20/60/100	15	5580120	772008	104	5574720	9287	9287	9294
126	2	5600000	20/60/100	15	5599920	773328	104	5594880	9301	9301	9308
127	2	5600000	20/60/100	15	5600010	773334	105	5594880	9301	9301	9308
128	2	5620000	20/60/100	15	5620080	774672	104	5615040	9315	9315	9322
129	2	5640000	20/60/100	15	5639880	775992	104	5635200	9329	9329	9336
130	2	5640000	20/60/100	15	5639970	775998	105	5635200	9329	9329	9336
131	2	5660000	20/60/100	15	5660040	777336	104	5655360	9343	9343	9350
132	2	5680000	20/60/100	15	5679840	778656	104	5674080	9356	9356	9364
133	2	5680000	20/60/100	15	5679930	778662	105	5674080	9356	9356	9364
134	2	5700000	20/60/100	15	5700000	780000	104	5694240	9370	9370	9378
135	2	5700000	20/60/100	15	5700090	780006	105	5694240	9370	9370	9378
136	2	5720000	20/60/100	15	5720160	781344	104	5714400	9384	9384	9392
137	3	5745000	20/60/100	15	5745000	783000	104	5740320	9402	9402	9409
138	3	5745000	20/60/100	15	5745090	783006	105	5740320	9402	9402	9409
139	3	5765000	20/60/100	15	5765160	784344	104	5760480	9416	9416	9423
140	3	5785000	20/60/100	15	5784960	785664	104	5779200	9429	9429	9437
141	3	5785000	20/60/100	15	5785050	785670	105	5779200	9429	9429	9437
142	3	5805000	20/60/100	15	5805120	787008	104	5799360	9443	9443	9451
143	3	5825000	20/60/100	15	5824920	788328	104	5819520	9457	9457	9464
144	3	5825000	20/60/100	15	5825010	788334	105	5819520	9457	9457	9464
145	3	5845000	20/60/100	15	5845080	789672	104	5839680	9471	9471	9478
146	3	5865000	20/60/100	15	5864880	790992	104	5859840	9485	9485	9492
147	3	5865000	20/60/100	15	5864970	790998	105	5859840	9485	9485	9492
148	3	5885000	20/60/100	15	5885040	792336	104	5880000	9499	9499	9506
149	3	5905000	20/60/100	15	5904840	793656	104	5900160	9513	9513	9520
150	3	5905000	20/60/100	15	5904930	793662	105	5900160	9513	9513	9520
151	1	5170000	40/80	15	5169900	744660	214	5154240	8995	8995	9016
152	1	5170000	40/80	15	5169990	744666	215	5154240	8995	8995	9016
153	1	5190000	40/80	15	5190060	746004	214	5174400	9009	9009	9030
154	1	5210000	40/80	15	5209860	747324	214	5194560	9023	9023	9044
155	1	5210000	40/80	15	5209950	747330	215	5194560	9023	9023	9044
156	1	5230000	40/80	15	5230020	748668	214	5214720	9037	9037	9058
157	1	5250000	40/80	15	5249820	749988	214	5234880	9051	9051	9072
158	1	5250000	40/80	15	5249910	749994	215	5234880	9051	9051	9072
159	1	5250000	40/80	15	5250000	750000	216	5234880	9051	9051	9072
160	1	5250000	40/80	15	5250180	750012	214	5234880	9051	9051	9072
161	1	5270000	40/80	15	5269980	751332	214	5255040	9065	9065	9086
162	1	5270000	40/80	15	5270070	751338	215	5255040	9065	9065	9086
163	1	5290000	40/80	15	5290140	752676	214	5275200	9079	9079	9100
164	1	5310000	40/80	15	5309940	753996	214	5295360	9093	9093	9114
165	1	5310000	40/80	15	5310030	754002	215	5295360	9093	9093	9114
166	1	5330000	40/80	15	5330100	755340	214	5315520	9107	9107	9128
167	2	5490000	40/80	15	5489940	765996	214	5475360	9218	9218	9239
168	2	5490000	40/80	15	5490030	766002	215	5475360	9218	9218	9239
169	2	5510000	40/80	15	5510100	767340	214	5495520	9232	9232	9253
170	2	5530000	40/80	15	5529900	768660	214	5514240	9245	9245	9266
171	2	5530000	40/80	15	5529990	768666	215	5514240	9245	9245	9266
172	2	5550000	40/80	15	5550060	770004	214	5534400	9259	9259	9280
173	2	5570000	40/80	15	5569860	771324	214	5554560	9273	9273	9294
174	2	5570000	40/80	15	5569950	771330	215	5554560	9273	9273	9294
175	2	5590000	40/80	15	5590020	772668	214	5574720	9287	9287	9308
176	2	5610000	40/80	15	5609820	773988	214	5594880	9301	9301	9322

TABLE 10-continued

Entry No.	UNII-Band	LTE Chn Raster [kHz]	BW [MHz]	Data SCS [kHz]	NR Chn Raster [kHz]	NR-ARFCN (N_{REF})	N_PRB	SS Raster [kHz]	GSCN	Min GSCN	Max GSCN
177	2	5610000	40/80	15	5609910	773994	215	5594880	9301	9301	9322
178	2	5610000	40/80	15	5610000	774000	216	5594880	9301	9301	9322
179	2	5610000	40/80	15	5610180	774012	214	5594880	9301	9301	9322
180	2	5630000	40/80	15	5629980	775332	214	5615040	9315	9315	9336
181	2	5630000	40/80	15	5630070	775338	215	5615040	9315	9315	9336
182	2	5650000	40/80	15	5650140	776676	214	5635200	9329	9329	9350
183	2	5670000	40/80	15	5669940	777996	214	5655360	9343	9343	9364
184	2	5670000	40/80	15	5670030	778002	215	5655360	9343	9343	9364
185	2	5690000	40/80	15	5690100	779340	214	5675520	9357	9357	9378
186	2	5710000	40/80	15	5709900	780660	214	5694240	9370	9370	9391
187	2	5710000	40/80	15	5709990	780666	215	5694240	9370	9370	9391
188	3	5755000	40/80	15	5754900	783660	214	5740320	9402	9402	9423
189	3	5755000	40/80	15	5754990	783666	215	5740320	9402	9402	9423
190	3	5775000	40/80	15	5775060	785004	214	5760480	9416	9416	9437
191	3	5795000	40/80	15	5794860	786324	214	5779200	9429	9429	9450
192	3	5795000	40/80	15	5794950	786330	215	5779200	9429	9429	9450
193	3	5815000	40/80	15	5815020	787668	214	5799360	9443	9443	9464
194	3	5835000	40/80	15	5834820	788988	214	5819520	9457	9457	9478
195	3	5835000	40/80	15	5834910	788994	215	5819520	9457	9457	9478
196	3	5835000	40/80	15	5835000	789000	216	5819520	9457	9457	9478
197	3	5835000	40/80	15	5835180	789012	214	5819520	9457	9457	9478
198	3	5855000	40/80	15	5854980	790332	214	5839680	9471	9471	9492
199	3	5855000	40/80	15	5855070	790338	215	5839680	9471	9471	9492
200	3	5875000	40/80	15	5875140	791676	214	5859840	9485	9485	9506
201	3	5895000	40/80	15	5894940	792996	214	5880000	9499	9499	9520
202	3	5895000	40/80	15	5895030	793002	215	5880000	9499	9499	9520

TABLE 11

Entry No.	k_SSB	RB Offset (Left)	RB Offset (Right)	Occ. Chn-Start [kHz]	Occ. Chn-End [kHz]	Left Guard [kHz]	Right Guard [kHz]	SSB Start [kHz]	SSB End [kHz]
101	0	0	64	5150640	5169345	632.5	647.5	5150640	5157810
102	0	0	65	5150640	5169525	632.5	467.5	5150640	5157810
103	0	0	64	5170800	5189505	792.5	487.5	5170800	5177970
104	0	2	62	5190600	5209305	592.5	687.5	5190960	5198130
105	0	2	63	5190600	5209485	592.5	507.5	5190960	5198130
106	0	2	62	5210760	5229465	752.5	527.5	5211120	5218290
107	0	4	60	5230560	5249265	552.5	727.5	5231280	5238450
108	0	4	61	5230560	5249445	552.5	547.5	5231280	5238450
109	0	4	60	5250720	5269425	712.5	567.5	5251440	5258610
110	0	6	58	5270520	5289225	512.5	767.5	5271600	5278770
111	0	6	59	5270520	5289405	512.5	587.5	5271600	5278770
112	0	6	58	5290680	5309385	672.5	607.5	5291760	5298930
113	0	0	64	5310480	5329185	472.5	807.5	5310480	5317650
114	0	0	65	5310480	5329365	472.5	627.5	5310480	5317650
115	0	0	64	5330640	5349345	632.5	647.5	5330640	5337810
116	0	0	65	5330640	5349525	632.5	467.5	5330640	5337810
117	0	6	58	5470680	5489385	672.5	607.5	5471760	5478930
118	0	0	64	5490480	5509185	472.5	807.5	5490480	5497650
119	0	0	65	5490480	5509365	472.5	627.5	5490480	5497650
120	0	0	64	5510640	5529345	632.5	647.5	5510640	5517810
121	0	0	65	5510640	5529525	632.5	467.5	5510640	5517810
122	0	0	64	5530800	5549505	792.5	487.5	5530800	5537970
123	0	2	62	5550600	5569305	592.5	687.5	5550960	5558130
124	0	2	63	5550600	5569485	592.5	507.5	5550960	5558130
125	0	2	62	5570760	5589465	752.5	527.5	5571120	5578290
126	0	4	60	5590560	5609265	552.5	727.5	5591280	5598450
127	0	4	61	5590560	5609445	552.5	547.5	5591280	5598450
128	0	4	60	5610720	5629425	712.5	567.5	5611440	5618610
129	0	6	58	5630520	5649225	512.5	767.5	5631600	5638770
130	0	6	59	5630520	5649405	512.5	587.5	5631600	5638770
131	0	6	58	5650680	5669385	672.5	607.5	5651760	5658930
132	0	0	64	5670480	5689185	472.5	807.5	5670480	5677650
133	0	0	65	5670480	5689365	472.5	627.5	5670480	5677650
134	0	0	64	5690640	5709345	632.5	647.5	5690640	5697810
135	0	0	65	5690640	5709525	632.5	467.5	5690640	5697810
136	0	0	64	5710800	5729505	792.5	487.5	5710800	5717970
137	0	6	58	5735640	5754345	632.5	647.5	5736720	5743890
138	0	6	59	5735640	5754525	632.5	467.5	5736720	5743890
139	0	6	58	5755800	5774505	792.5	487.5	5756880	5764050
140	0	0	64	5775600	5794305	592.5	687.5	5775600	5782770
141	0	0	65	5775600	5794485	592.5	507.5	5775600	5782770

TABLE 11-continued

Entry No.	k_SSB	RB Offset (Left)	RB Offset (Right)	Occ. Chn-Start [kHz]	Occ. Chn-End [kHz]	Left Guard [kHz]	Right Guard [kHz]	SSB Start [kHz]	SSB End [kHz]
142	0	0	64	5795760	5814465	752.5	527.5	5795760	5802930
143	0	2	62	5815560	5834265	552.5	727.5	5815920	5823090
144	0	2	63	5815560	5834445	552.5	547.5	5815920	5823090
145	0	2	62	5835720	5854425	712.5	567.5	5836080	5843250
146	0	4	60	5855520	5874225	512.5	767.5	5856240	5863410
147	0	4	61	5855520	5874405	512.5	587.5	5856240	5863410
148	0	4	60	5875680	5894385	672.5	607.5	5876400	5883570
149	0	6	58	5895480	5914185	472.5	807.5	5896560	5903730
150	0	6	59	5895480	5914365	472.5	627.5	5896560	5903730
151	0	0	174	5150640	5189145	632.5	847.5	5150640	5157810
152	0	0	175	5150640	5189325	632.5	667.5	5150640	5157810
153	0	0	174	5170800	5209305	792.5	687.5	5170800	5177970
154	0	2	172	5190600	5229105	592.5	887.5	5190960	5198130
155	0	2	173	5190600	5229285	592.5	707.5	5190960	5198130
156	0	2	172	5210760	5249265	752.5	727.5	5211120	5218290
157	0	4	170	5230560	5269065	552.5	927.5	5231280	5238450
158	0	4	171	5230560	5269245	552.5	747.5	5231280	5238450
159	0	4	172	5230560	5269425	552.5	567.5	5231280	5238450
160	0	2	172	5230920	5269425	912.5	567.5	5231280	5238450
161	0	4	170	5250720	5289225	712.5	767.5	5251440	5258610
162	0	4	171	5250720	5289405	712.5	587.5	5251440	5258610
163	0	4	170	5270880	5309385	872.5	607.5	5271600	5278770
164	0	6	168	5290680	5329185	672.5	807.5	5291760	5298930
165	0	6	169	5290680	5329365	672.5	627.5	5291760	5298930
166	0	6	168	5310840	5349345	832.5	647.5	5311920	5319090
167	0	6	168	5470680	5509185	672.5	807.5	5471760	5478930
168	0	6	169	5470680	5509365	672.5	627.5	5471760	5478930
169	0	6	168	5490840	5529345	832.5	647.5	5491920	5499090
170	0	0	174	5510640	5549145	632.5	847.5	5510640	5517810
171	0	0	175	5510640	5549325	632.5	667.5	5510640	5517810
172	0	0	174	5530800	5569305	792.5	687.5	5530800	5537970
173	0	2	172	5550600	5589105	592.5	887.5	5550960	5558130
174	0	2	173	5550600	5589285	592.5	707.5	5550960	5558130
175	0	2	172	5570760	5609265	752.5	727.5	5571120	5578290
176	0	4	170	5590560	5629065	552.5	927.5	5591280	5598450
177	0	4	171	5590560	5629245	552.5	747.5	5591280	5598450
178	0	4	172	5590560	5629425	552.5	567.5	5591280	5598450
179	0	2	172	5590920	5629425	912.5	567.5	5591280	5598450
180	0	4	170	5610720	5649225	712.5	767.5	5611440	5618610
181	0	4	171	5610720	5649405	712.5	587.5	5611440	5618610
182	0	4	170	5630880	5669385	872.5	607.5	5631600	5638770
183	0	6	168	5650680	5689185	672.5	807.5	5651760	5658930
184	0	6	169	5650680	5689365	672.5	627.5	5651760	5658930
185	0	6	168	5670840	5709345	832.5	647.5	5671920	5679090
186	0	0	174	5690640	5729145	632.5	847.5	5690640	5697810
187	0	0	175	5690640	5729325	632.5	667.5	5690640	5697810
188	0	6	168	5735640	5774145	632.5	847.5	5736720	5743890
189	0	6	169	5735640	5774325	632.5	667.5	5736720	5743890
190	0	6	168	5755800	5794305	792.5	687.5	5756880	5764050
191	0	0	174	5775600	5814105	592.5	887.5	5775600	5782770
192	0	0	175	5775600	5814285	592.5	707.5	5775600	5782770
193	0	0	174	5795760	5834265	752.5	727.5	5795760	5802930
194	0	2	172	5815560	5854065	552.5	927.5	5815920	5823090
195	0	2	173	5815560	5854245	552.5	747.5	5815920	5823090
196	0	2	174	5815560	5854425	552.5	567.5	5815920	5823090
197	0	0	174	5815920	5854425	912.5	567.5	5815920	5823090
198	0	2	172	5835720	5874225	712.5	767.5	5836080	5843250
199	0	2	173	5835720	5874405	712.5	587.5	5836080	5843250
200	0	2	172	5855880	5894385	872.5	607.5	5856240	5863410
201	0	4	170	5875680	5914185	672.5	807.5	5876400	5883570
202	0	4	171	5875680	5914365	672.5	627.5	5876400	5883570

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Example Set of Channel Raster & SSB Raster Entries for 30 kHz & 15 kHz with 1 Unique Channel Raster Entry Per LTE 20 MHz Channel

In the example channel raster and SSB raster entries shown in Table 8 900, Table 9 1000, Table 10, and Table 11, there may be multiple entries that correspond to the same LTE channel raster. To avoid the additional channel raster entries, further down selection may be performed to select NR channel raster entries that only support 50 PRB and choose only 1 NR channel entry per LTE channel raster entry for 20 MHz channels and only support 104 PRB or 106 PRB for 40 MHz channels.

FIG. 11A through FIG. 11C illustrate a Table 12 1100 that shows NR channel raster entries that could be applicable for both 30 KHz data subcarrier operation.

Example Set of Channel Raster & SSB Raster Entries for 30 KHz & 15 kHz with 1 Unique Channel Raster Entry Per LTE 20 MHz Channel that Results in Identical Channel Raster Entry Between 30 kHz and 15 kHz

In the example channel raster and SSB raster entries shown in Table 8 900, Table 9 1000, Table 10, and Table 11, there may be multiple entries that could correspond to the same LTE channel raster. To avoid the additional channel raster entries, further down selection may be performed to

select NR channel raster entries that only support 50 PRB and choose only 1 NR channel entry per LTE channel raster entry for 20 MHz channels, and only support 104 or 106 PRB for 40 Mhz channels. Additionally, the NR channel raster entries that are common for both 15 kHz and 30 kHz can be selected.

FIG. 12A through FIG. 12C. illustrate a Table 13 1200 and FIG. 13A through FIG. 13C illustrate a Table 14 1300 that show NR channel raster entries that could be applicable for both 30 kHz and 15 KHz data subcarrier operation. This compacts the total number of channel entries across all data subcarriers. The NR channel raster entries of Table 13 1200 and Table 14 1300 should be identical. However, the supported GSCN ranges for each channel raster entry might be slightly different. To support both 30 kHz and 15 KHz, the GSCN should be selected such that the same GSCN can support both 30 kHz and 15 kHz data subcarrier operations. Example Set of Channel Raster & SSB Raster Entries for 30 kHz & 15 kHz with 1 Unique Channel Raster Entry Per LTE

20 MHz Channel that Maximizes the Supported Number of PRBs

The example channel raster and SSB raster entries shown in Table 8 to Table 14, provide channel raster entries that have uniform number of PRBs that could be supported in channel. It is possible to squeeze extra system capacity for certain NR channel raster points by utilizing more PRBs that still satisfy all the conditions mentioned above (e.g. minimum guard band, PRB grid alignment, PRB and SSB PRB grid alignment, etc.).

Accordingly, down selection is performed to select NR channel raster entries that support the maximum number of PRB and choose only 1 NR channel entry per LTE channel raster entry for 20 MHz. This is shown in Table 15 1400 illustrated in FIG. 14A through FIG. 14C and Table 16 as provided below. This may result in slightly different NR channel raster entry for the 30 kHz and 15 kHz data subcarrier cases.

TABLE 16

UNII-Band	LTE Chn Raster [kHz]	Bandwidth [MHz]	Data SCS [kHz]	NR Chn Raster [kHz]	NR-ARFCN (N _{REF})	N_PRB	SS Raster [kHz]	GSCN	Min GSCN	Max GSCN
1	5160000	20/60/100	15	5160090	744006	105	5154240	8995	8995	9003
1	5180000	20/60/100	15	5180160	745344	104	5174400	9009	9009	9017
1	5200000	20/60/100	15	5200050	746670	105	5194560	9023	9023	9030
1	5220000	20/60/100	15	5220120	748008	104	5214720	9037	9037	9044
1	5240000	20/60/100	15	5240010	749334	105	5234880	9051	9051	9058
1	5260000	20/60/100	15	5260080	750672	104	5255040	9065	9065	9072
1	5280000	20/60/100	15	5279970	751998	105	5275200	9079	9079	9086
1	5300000	20/60/100	15	5300040	753336	104	5295360	9093	9093	9100
1	5320000	20/60/100	15	5319930	754662	105	5314080	9106	9106	9114
1	5340000	20/60/100	15	5340090	756006	105	5334240	9120	9120	9128
2	5480000	20/60/100	15	5480040	765336	104	5475360	9218	9218	9225
2	5500000	20/60/100	15	5499930	766662	105	5494080	9231	9231	9239
2	5520000	20/60/100	15	5520090	768006	105	5514240	9245	9245	9253
2	5540000	20/60/100	15	5540160	769344	104	5534400	9259	9259	9267
2	5560000	20/60/100	15	5560050	770670	105	5554560	9273	9273	9280
2	5580000	20/60/100	15	5580120	772008	104	5574720	9287	9287	9294
2	5600000	20/60/100	15	5600010	773334	105	5594880	9301	9301	9308
2	5620000	20/60/100	15	5620080	774672	104	5615040	9315	9315	9322
2	5640000	20/60/100	15	5639970	775998	105	5635200	9329	9329	9336
2	5660000	20/60/100	15	5660040	777336	104	5655360	9343	9343	9350
2	5680000	20/60/100	15	5679930	778662	105	5674080	9356	9356	9364
2	5700000	20/60/100	15	5700090	780006	105	5694240	9370	9370	9378
2	5720000	20/60/100	15	5720160	781344	104	5714400	9384	9384	9392
3	5745000	20/60/100	15	5745090	783006	105	5740320	9402	9402	9409
3	5765000	20/60/100	15	5765160	784344	104	5760480	9416	9416	9423
3	5785000	20/60/100	15	5785050	785670	105	5779200	9429	9429	9437
3	5805000	20/60/100	15	5805120	787008	104	5799360	9443	9443	9451
3	5825000	20/60/100	15	5825010	788334	105	5819520	9457	9457	9464
3	5845000	20/60/100	15	5845080	789672	104	5839680	9471	9471	9478
3	5865000	20/60/100	15	5864970	790998	105	5859840	9485	9485	9492
3	5885000	20/60/100	15	5885040	792336	104	5880000	9499	9499	9506
3	5905000	20/60/100	15	5904930	793662	105	5900160	9513	9513	9520
1	5170000	40/80	15	5169990	744666	215	5154240	8995	8995	9016
1	5190000	40/80	15	5190060	746004	214	5174400	9009	9009	9030
1	5210000	40/80	15	5209950	747330	215	5194560	9023	9023	9044
1	5230000	40/80	15	5230020	748668	214	5214720	9037	9037	9058
1	5250000	40/80	15	5250000	750000	216	5234880	9051	9051	9072
1	5270000	40/80	15	5270070	751338	215	5255040	9065	9065	9086
1	5290000	40/80	15	5290140	752676	214	5275200	9079	9079	9100
1	5310000	40/80	15	5310030	754002	215	5295360	9093	9093	9114
1	5330000	40/80	15	5330100	755340	214	5315520	9107	9107	9128
2	5490000	40/80	15	5490030	766002	215	5475360	9218	9218	9239
2	5510000	40/80	15	5510100	767340	214	5495520	9232	9232	9253
2	5530000	40/80	15	5529990	768666	215	5514240	9245	9245	9266
2	5550000	40/80	15	5550060	770004	214	5534400	9259	9259	9280
2	5570000	40/80	15	5569950	771330	215	5554560	9273	9273	9294
2	5590000	40/80	15	5590020	772668	214	5574720	9287	9287	9308
2	5610000	40/80	15	5610000	774000	216	5594880	9301	9301	9322
2	5630000	40/80	15	5630070	775338	215	5615040	9315	9315	9336
2	5650000	40/80	15	5650140	776676	214	5635200	9329	9329	9350

TABLE 16-continued

UNII- Band	LTE Chn Raster [kHz]	BW [MHz]	Data SCS [kHz]	NR Chn Raster [kHz]	NR- ARFCN (<i>N_{REF}</i>)	N_PRB	SS Raster [kHz]	GSCN	Min GSCN	Max GSCN
2	5670000	40/80	15	5670030	778002	215	5655360	9343	9343	9364
2	5690000	40/80	15	5690100	779340	214	5675520	9357	9357	9378
2	5710000	40/80	15	5709990	780666	215	5694240	9370	9370	9391
3	5755000	40/80	15	5754990	783666	215	5740320	9402	9402	9423
3	5775000	40/80	15	5775060	785004	214	5760480	9416	9416	9437
3	5795000	40/80	15	5794950	786330	215	5779200	9429	9429	9450
3	5815000	40/80	15	5815020	787668	214	5799360	9443	9443	9464
3	5835000	40/80	15	5835000	789000	216	5819520	9457	9457	9478
3	5855000	40/80	15	5855070	790338	215	5839680	9471	9471	9492
3	5875000	40/80	15	5875140	791676	214	5859840	9485	9485	9506
3	5895000	40/80	15	5895030	793002	215	5880000	9499	9499	9520

Example System Architecture

In certain embodiments, 5G System architecture supports data connectivity and services enabling deployments to use techniques such as Network Function Virtualization and Software Defined Networking. The 5G System architecture may leverage service-based interactions between Control Plane Network Functions. Separating User Plane functions from the Control Plane functions allows independent scalability, evolution, and flexible deployments (e.g., centralized location or distributed (remote) location). Modularized function design allows for function re-use and may enable flexible and efficient network slicing. A Network Function and its Network Function Services may interact with another NF and its Network Function Services directly or indirectly via a Service Communication Proxy. Another intermediate function may help route Control Plane messages. The architecture minimizes dependencies between the AN and the CN. The architecture may include a converged core network with a common AN-CN interface that integrates different Access Types (e.g., 3GPP access and non-3GPP access). The architecture may also support a unified authentication framework, stateless NFs where the compute resource is decoupled from the storage resource, capability exposure, concurrent access to local and centralized services (to support low latency services and access to local data networks, User Plane functions can be deployed close to the AN), and/or roaming with both Home routed traffic as well as Local breakout traffic in the visited PLMN.

The 5G architecture may be defined as service-based and the interaction between network functions may include a service-based representation, where network functions (e.g., AMF) within the Control Plane enable other authorized network functions to access their services. The service-based representation may also include point-to-point reference points. A reference point representation may also be used to show the interactions between the NF services in the network functions described by point-to-point reference point (e.g., N11) between any two network functions (e.g., AMF and SMF).

FIG. 5 illustrates a service based architecture 500 in 5GS according to one embodiment. As described in 3GPP TS 23.501, the service based architecture 500 comprises NFs such as an NSSF 502, a NEF 504, an NRF 506, a PCF 508, a UDM 510, an AUSF 512, an AMF 514, an SMF 516, for communication with a UE 520, a (R) AN 522, a UPF 524, and a DN 526. The NFs and NF services can communicate directly, referred to as Direct Communication, or indirectly via a SCP 518, referred to as Indirect Communication. FIG. 5 also shows corresponding service-based interfaces including Nutm, Naf, Nudm, Npcf, Nsmf, Nnrf, Namf, Nnef,

Nnssf, and Nausf, as well as reference points N1, N2, N3, N4, and N6. A few example functions provided by the NFs shown in FIG. 5 are described below.

The NSSF 502 supports functionality such as: selecting the set of Network Slice instances serving the UE; determining the Allowed NSSAI and, if needed, mapping to the Subscribed S-NSSAIs; determining the Configured NSSAI and, if needed, the mapping to the Subscribed S-NSSAIs; and/or determining the AMF Set to be used to serve the UE, or, based on configuration, a list of candidate AMF(s), possibly by querying the NRF.

The NEF 504 supports exposure of capabilities and events. NF capabilities and events may be securely exposed by the NEF 504 (e.g., for 3rd party, Application Functions, and/or Edge Computing). The NEF 504 may store/retrieve information as structured data using a standardized interface (Nudr) to a UDR. The NEF 504 may also secure provision of information from an external application to 3GPP network and may provide for the Application Functions to securely provide information to the 3GPP network (e.g., expected UE behavior, 5GLAN group information, and service specific information), wherein the NEF 504 may authenticate and authorize and assist in throttling the Application Functions. The NEF 504 may provide translation of internal-external information by translating between information exchanged with the AF and information exchanged with the internal network function. For example, the NEF 504 translates between an AF-Service-Identifier and internal 5G Core information such as DNN and S-NSSAI. The NEF 504 may handle masking of network and user sensitive information to external AF's according to the network policy. The NEF 504 may receive information from other network functions (based on exposed capabilities of other network functions), and stores the received information as structured data using a standardized interface to a UDR. The stored information can be accessed and re-exposed by the NEF 504 to other network functions and Application Functions, and used for other purposes such as analytics. For external exposure of services related to specific UE(s), the NEF 504 may reside in the HPLMN. Depending on operator agreements, the NEF 504 in the HPLMN may have interface(s) with NF(s) in the VPLMN. When a UE is capable of switching between EPC and 5GC, an SCEF+NEF may be used for service exposure.

The NRF 506 supports service discovery function by receiving an NF Discovery Request from an NF instance or SCP and providing the information of the discovered NF instances to the NF instance or SCP. The NRF 506 may also support P-CSCF discovery (specialized case of AF discovery by SMF), maintains the NF profile of available NF

instances and their supported services, and/or notify about newly registered/updated/deregistered NF instances along with its NF services to the subscribed NF service consumer or SCP. In the context of Network Slicing, based on network implementation, multiple NRFs can be deployed at different levels such as a PLMN level (the NRF is configured with information for the whole PLMN), a shared-slice level (the NRF is configured with information belonging to a set of Network Slices), and/or a slice-specific level (the NRF is configured with information belonging to an S-NSSAI). In the context of roaming, multiple NRFs may be deployed in the different networks, wherein the NRF(s) in the Visited PLMN (known as the vNRF) are configured with information for the visited PLMN, and wherein the NRF(s) in the Home PLMN (known as the hNRF) are configured with information for the home PLMN, referenced by the vNRF via an N27 interface.

The PCF **508** supports a unified policy framework to govern network behavior. The PCF **508** provides policy rules to Control Plane function(s) to enforce them. The PCF **508** accesses subscription information relevant for policy decisions in a Unified Data Repository (UDR). The PCF **508** may access the UDR located in the same PLMN as the PCF.

The UDM **510** supports generation of 3GPP AKA Authentication Credentials, User Identification Handling (e.g., storage and management of SUPI for each subscriber in the 5G system), de-concealment of a privacy-protected subscription identifier (SUCI), access authorization based on subscription data (e.g., roaming restrictions), UE's Serving NF Registration Management (e.g., storing serving AMF for UE, storing serving SMF for UE's PDU Session), service/session continuity (e.g., by keeping SMF/DNN assignment of ongoing sessions, MT-SMS delivery, Lawful Intercept Functionality (especially in outbound roaming cases where a UDM is the only point of contact for LI), subscription management, SMS management, 5GLAN group management handling, and/or external parameter provisioning (Expected UE Behavior parameters or Network Configuration parameters). To provide such functionality, the UDM **510** uses subscription data (including authentication data) that may be stored in a UDR, in which case a UDM implements the application logic and may not require an internal user data storage and several different UDMs may serve the same user in different transactions. The UDM **510** may be located in the HPLMN of the subscribers it serves, and may access the information of the UDR located in the same PLMN.

The AF **528** interacts with the Core Network to provide services that, for example, support the following: application influence on traffic routing; accessing the NEF **504**; interacting with the Policy framework for policy control; and/or IMS interactions with 5GC. Based on operator deployment, Application Functions considered to be trusted by the operator can be allowed to interact directly with relevant Network Functions. Application Functions not allowed by the operator to access directly the Network Functions may use the external exposure framework via the NEF **504** to interact with relevant Network Functions.

The AUSF **512** supports authentication for 3GPP access and untrusted non-3GPP access. The AUSF **512** may also provide support for Network Slice-Specific Authentication and Authorization.

The AMF **514** supports termination of RAN CP interface (N2), termination of NAS (N1) for NAS ciphering and integrity protection, registration management, connection management, reachability management, Mobility Management, lawful intercept (for AMF events and interface to LI System), transport for SM messages between UE and SMF,

transparent proxy for routing SM messages, Access Authentication, Access Authorization, transport for SMS messages between UE and SMSF, SEAF, Location Services management for regulatory services, transport for Location Services messages between UE and LMF as well as between RAN and LMF, EPS Bearer ID allocation for interworking with EPS, UE mobility event notification, Control Plane CIoT 5GS Optimization, User Plane CIoT 5GS Optimization, provisioning of external parameters (Expected UE Behavior parameters or Network Configuration parameters), and/or Network Slice-Specific Authentication and Authorization. Some or all of the AMF functionalities may be supported in a single instance of the AMF **514**. Regardless of the number of Network functions, in certain embodiments there is only one NAS interface instance per access network between the UE and the CN, terminated at one of the Network functions that implements at least NAS security and Mobility Management. The AMF **514** may also include policy related functionalities.

In addition to the functionalities described above, the AMF **514** may include the following functionality to support non-3GPP access networks: support of N2 interface with N3IWF/TNGF, over which some information (e.g., 3GPP Cell Identification) and procedures (e.g., Handover related) defined over 3GPP access may not apply, and non-3GPP access specific information may be applied that do not apply to 3GPP accesses; support of NAS signaling with a UE over N3IWF/TNGF, wherein some procedures supported by NAS signaling over 3GPP access may be not applicable to untrusted non-3GPP (e.g., Paging) access; support of authentication of UEs connected over N3IWF/TNGF; management of mobility, authentication, and separate security context state(s) of a UE connected via a non-3GPP access or connected via a 3GPP access and a non-3GPP access simultaneously; support a coordinated RM management context valid over a 3GPP access and a Non 3GPP access; and/or support dedicated CM management contexts for the UE for connectivity over non-3GPP access. Not all of the above functionalities may be required to be supported in an instance of a Network Slice.

The SMF **516** supports Session Management (e.g., Session Establishment, modify and release, including tunnel maintain between UPF and AN node), UE IP address allocation & management (including optional Authorization) wherein the UE IP address may be received from a UPF or from an external data network, DHCPv4 (server and client) and DHCPv6 (server and client) functions, functionality to respond to Address Resolution Protocol requests and/or IPV6 Neighbor Solicitation requests based on local cache information for the Ethernet PDUs (e.g., the SMF responds to the ARP and/or the IPV6 Neighbor Solicitation Request by providing the MAC address corresponding to the IP address sent in the request), selection and control of User Plane functions including controlling the UPF to proxy ARP or IPV6 Neighbor Discovery or to forward all ARP/IPV6 Neighbor Solicitation traffic to the SMF for Ethernet PDU Sessions, traffic steering configuration at the UPF to route traffic to proper destinations, 5G VN group management (e.g., maintain the topology of the involved PSA UPFs, establish and release the N19 tunnels between PSA UPFs, configure traffic forwarding at UPF to apply local switching, and/or N6-based forwarding or N19-based forwarding), termination of interfaces towards Policy control functions, lawful intercept (for SM events and interface to LI System), charging data collection and support of charging interfaces, control and coordination of charging data collection at the UPF, termination of SM parts of NAS messages, Downlink

Data Notification, Initiator of AN specific SM information sent via AMF over N2 to AN, determination of SSC mode of a session, Control Plane CIoT 5GS Optimization, header compression, acting as I-SMF in deployments where I-SMF can be inserted/removed/relocated, provisioning of external parameters (Expected UE Behavior parameters or Network Configuration parameters), P-CSCF discovery for IMS services, roaming functionality (e.g., handle local enforcement to apply QoS SLAs (VPLMN), charging data collection and charging interface (VPLMN), and/or lawful intercept (in VPLMN for SM events and interface to LI System), interaction with external DN for transport of signaling for PDU Session authentication/authorization by external DN, and/or instructing UPF and NG-RAN to perform redundant transmission on N3/N9 interfaces. Some or all of the SMF functionalities may be supported in a single instance of a SMF. However, in certain embodiments, not all of the functionalities are required to be supported in an instance of a Network Slice. In addition to the functionalities, the SMF 516 may include policy related functionalities.

The SCP 518 includes one or more of the following functionalities: Indirect Communication; Delegated Discovery; message forwarding and routing to destination NF/NF services; communication security (e.g., authorization of the NF Service Consumer to access the NF Service Producer's API), load balancing, monitoring, overload control, etc.; and/or optionally interact with the UDR, to resolve the UDM Group ID/UDR Group ID/AUSF Group ID/PCF Group ID/CHF Group ID/HSS Group ID based on UE identity (e.g., SUPI or IMPI/IMPU). Some or all of the SCP functionalities may be supported in a single instance of an SCP. In certain embodiments, the SCP 518 may be deployed in a distributed manner and/or more than one SCP can be present in the communication path between NF Services. SCPs can be deployed at PLMN level, shared-slice level, and slice-specific level. It may be left to operator deployment to ensure that SCPs can communicate with relevant NRFs.

The UE 520 may include a device with radio communication capabilities. For example, the UE 520 may comprise a smartphone (e.g., handheld touchscreen mobile computing devices connectable to one or more cellular networks). The UE 520 may also comprise any mobile or non-mobile computing device, such as Personal Data Assistants (PDAs), pagers, laptop computers, desktop computers, wireless handsets, or any computing device including a wireless communications interface. A UE may also be referred to as a client, mobile, mobile device, mobile terminal, user terminal, mobile unit, mobile station, mobile user, subscriber, user, remote station, access agent, user agent, receiver, radio equipment, reconfigurable radio equipment, or reconfigurable mobile device. The UE 520 may comprise an IoT UE, which can comprise a network access layer designed for low-power IoT applications utilizing short-lived UE connections. An IoT UE can utilize technologies (e.g., M2M, MTC, or mMTC technology) for exchanging data with an MTC server or device via a PLMN, other UEs using ProSe or D2D communications, sensor networks, or IoT networks. The M2M or MTC exchange of data may be a machine-initiated exchange of data. An IoT network describes interconnecting IoT UEs, which may include uniquely identifiable embedded computing devices (within the Internet infrastructure). The IoT UEs may execute background applications (e.g., keep-alive messages, status updates, etc.) to facilitate the connections of the IoT network.

The UE 520 may be configured to connect or communicatively couple with the (R) AN 522 through a radio interface 530, which may be a physical communication

interface or layer configured to operate with cellular communication protocols such as a GSM protocol, a CDMA network protocol, a Push-to-Talk (PTT) protocol, a PTT over Cellular (POC) protocol, a UMTS protocol, a 3GPP LTE protocol, a 5G protocol, a NR protocol, and the like. For example, the UE 520 and the (R) AN 522 may use a Uu interface (e.g., an LTE-Uu interface) to exchange control plane data via a protocol stack comprising a PHY layer, a MAC layer, an RLC layer, a PDCP layer, and an RRC layer. A DL transmission may be from the (R) AN 522 to the UE 520 and a UL transmission may be from the UE 520 to the (R) AN 522. The UE 520 may further use a sidelink to communicate directly with another UE (not shown) for D2D, P2P, and/or ProSe communication. For example, a ProSe interface may comprise one or more logical channels, including but not limited to a Physical Sidelink Control Channel (PSCCH), a Physical Sidelink Shared Channel (PSSCH), a Physical Sidelink Discovery Channel (PSDCH), and a Physical Sidelink Broadcast Channel (PSBCH).

The (R) AN 522 can include one or more access nodes, which may be referred to as base stations (BSs), NodeBs, evolved NodeBs (eNBs), next Generation NodeBs (gNB), RAN nodes, controllers, transmission reception points (TRPs), and so forth, and can comprise ground stations (e.g., terrestrial access points) or satellite stations providing coverage within a geographic area (e.g., a cell). The (R) AN 522 may include one or more RAN nodes for providing macrocells, picocells, femtocells, or other types of cells. A macrocell may cover a relatively large geographic area (e.g., several kilometers in radius) and may allow unrestricted access by UEs with service subscription. A picocell may cover a relatively small geographic area and may allow unrestricted access by UEs with service subscription. A femtocell may cover a relatively small geographic area (e.g., a home) and may allow restricted access by UEs having an association with the femtocell (e.g., UEs in a Closed Subscriber Group (CSG), UEs for users in the home, etc.).

Although not shown, multiple RAN nodes (such as the (R) AN 522) may be used, wherein an Xn interface is defined between two or more nodes. In some implementations, the Xn interface may include an Xn user plane (Xn-U) interface and an Xn control plane (Xn-C) interface. The Xn-U may provide non-guaranteed delivery of user plane PDUs and support/provide data forwarding and flow control functionality. The Xn-C may provide management and error handling functionality, functionality to manage the Xn-C interface; mobility support for the UE 520 in a connected mode (e.g., CM-CONNECTED) including functionality to manage the UE mobility for connected mode between one or more (R) AN nodes. The mobility support may include context transfer from an old (source) serving (R) AN node to new (target) serving (R) AN node; and control of user plane tunnels between old (source) serving (R) AN node to new (target) serving (R) AN node.

The UPF 524 may act as an anchor point for intra-RAT and inter-RAT mobility, an external PDU session point of interconnect to the DN 526, and a branching point to support multi-homed PDU session. The UPF 524 may also perform packet routing and forwarding, packet inspection, enforce user plane part of policy rules, lawfully intercept packets (UP collection); traffic usage reporting, perform QoS handling for user plane (e.g. packet filtering, gating, UL/DL rate enforcement), perform Uplink Traffic verification (e.g., SDF to QoS flow mapping), transport level packet marking in the uplink and downlink, and downlink packet buffering and downlink data notification triggering. The UPF 524 may include an uplink classifier to support routing traffic flows to

a data network. The DN 526 may represent various network operator services, Internet access, or third party services. The DN 526 may include, for example, an application server.

FIG. 6 is a block diagram of an example UE 600 configurable according to various embodiments of the present disclosure, including by execution of instructions on a computer-readable medium that correspond to any of the example methods and/or procedures described herein. The UE 600 comprises one or more processor 602, transceiver 604, memory 606, user interface 608, and control interface 610.

The one or more processor 602 may include, for example, an application processor, an audio digital signal processor, a central processing unit, and/or one or more baseband processors. Each of the one or more processor 602 may include internal memory and/or may include interface(s) to communication with external memory (including the memory 606). The internal or external memory can store software code, programs, and/or instructions for execution by the one or more processor 602 to configure and/or facilitate the UE 600 to perform various operations, including operations described herein. For example, execution of the instructions can configure the UE 600 to communicate using one or more wired or wireless communication protocols, including one or more wireless communication protocols standardized by 3GPP such as those commonly known as 5G/NR, LTE, LTE-A, UMTS, HSPA, GSM, GPRS, EDGE, etc., or any other current or future protocols that can be utilized in conjunction with the one or more transceiver 604, user interface 608, and/or control interface 610. As another example, the one or more processor 602 may execute program code stored in the memory 606 or other memory that corresponds to MAC, RLC, PDCP, and RRC layer protocols standardized by 3GPP (e.g., for NR and/or LTE). As a further example, the processor 602 may execute program code stored in the memory 606 or other memory that, together with the one or more transceiver 604, implements corresponding PHY layer protocols, such as Orthogonal Frequency Division Multiplexing (OFDM), Orthogonal Frequency Division Multiple Access (OFDMA), and Single-Carrier Frequency Division Multiple Access (SC-FDMA).

The memory 606 may comprise memory area for the one or more processor 602 to store variables used in protocols, configuration, control, and other functions of the UE 600, including operations corresponding to, or comprising, any of the example methods and/or procedures described herein. Moreover, the memory 606 may comprise non-volatile memory (e.g., flash memory), volatile memory (e.g., static or dynamic RAM), or a combination thereof. Furthermore, the memory 606 may interface with a memory slot by which removable memory cards in one or more formats (e.g., SD Card, Memory Stick, Compact Flash, etc.) can be inserted and removed.

The one or more transceiver 604 may include radio-frequency transmitter and/or receiver circuitry that facilitates the UE 600 to communicate with other equipment supporting like wireless communication standards and/or protocols. For example, the one or more transceiver 604 may include switches, mixer circuitry, amplifier circuitry, filter circuitry, and synthesizer circuitry. Such RF circuitry may include a receive signal path with circuitry to down-convert RF signals received from a front-end module (FEM) and provide baseband signals to a baseband processor of the one or more processor 602. The RF circuitry may also include a transmit signal path which may include circuitry to up-convert baseband signals provided by a baseband processor

and provide RF output signals to the FEM for transmission. The FEM may include a receive signal path that may include circuitry configured to operate on RF signals received from one or more antennas, amplify the received signals and provide the amplified versions of the received signals to the RF circuitry for further processing. The FEM may also include a transmit signal path that may include circuitry configured to amplify signals for transmission provided by the RF circuitry for transmission by one or more antennas. In various embodiments, the amplification through the transmit or receive signal paths may be done solely in the RF circuitry, solely in the FEM, or in both the RF circuitry and the FEM circuitry. In some embodiments, the FEM circuitry may include a TX/RX switch to switch between transmit mode and receive mode operation.

In some exemplary embodiments, the one or more transceiver 604 includes a transmitter and a receiver that enable device 1200 to communicate with various 5G/NR networks according to various protocols and/or methods proposed for standardization by 3 GPP and/or other standards bodies. For example, such functionality can operate cooperatively with the one or more processor 602 to implement a PHY layer based on OFDM, OFDMA, and/or SC-FDMA technologies, such as described herein with respect to other figures.

The user interface 608 may take various forms depending on particular embodiments, or can be absent from the UE 600. In some embodiments, the user interface 608 includes a microphone, a loudspeaker, slidable buttons, depressible buttons, a display, a touchscreen display, a mechanical or virtual keypad, a mechanical or virtual keyboard, and/or any other user-interface features commonly found on mobile phones. In other embodiments, the UE 600 may comprise a tablet computing device including a larger touchscreen display. In such embodiments, one or more of the mechanical features of the user interface 608 may be replaced by comparable or functionally equivalent virtual user interface features (e.g., virtual keypad, virtual buttons, etc.) implemented using the touchscreen display, as familiar to persons of ordinary skill in the art. In other embodiments, the UE 600 may be a digital computing device, such as a laptop computer, desktop computer, workstation, etc. that comprises a mechanical keyboard that can be integrated, detached, or detachable depending on the particular exemplary embodiment. Such a digital computing device can also comprise a touch screen display. Many example embodiments of the UE 600 having a touch screen display are capable of receiving user inputs, such as inputs related to exemplary methods and/or procedures described herein or otherwise known to persons of ordinary skill in the art.

In some exemplary embodiments of the present disclosure, the UE 600 may include an orientation sensor, which can be used in various ways by features and functions of the UE 600. For example, the UE 600 can use outputs of the orientation sensor to determine when a user has changed the physical orientation of the UE 600's touch screen display. An indication signal from the orientation sensor can be available to any application program executing on the UE 600, such that an application program can change the orientation of a screen display (e.g., from portrait to landscape) automatically when the indication signal indicates an approximate 90-degree change in physical orientation of the device. In this manner, the application program can maintain the screen display in a manner that is readable by the user, regardless of the physical orientation of the device. In addition, the output of the orientation sensor can be used in conjunction with various exemplary embodiments of the present disclosure.

The control interface **610** may take various forms depending on particular embodiments. For example, the control interface **610** may include an RS-232 interface, an RS-485 interface, a USB interface, an HDMI interface, a Bluetooth interface, an IEEE (“Firewire”) interface, an I²C interface, a PCMCIA interface, or the like. In some exemplary embodiments of the present disclosure, control interface **1260** can comprise an IEEE 802.3 Ethernet interface such as described above. In some embodiments of the present disclosure, the control interface **610** may include analog interface circuitry including, for example, one or more digital-to-analog (D/A) and/or analog-to-digital (A/D) converters.

Persons of ordinary skill in the art can recognize the above list of features, interfaces, and radio-frequency communication standards is merely exemplary, and not limiting to the scope of the present disclosure. In other words, the UE **600** may include more functionality than is shown in FIG. **6** including, for example, a video and/or still-image camera, microphone, media player and/or recorder, etc. Moreover, the one or more transceiver **604** may include circuitry for communication using additional radio-frequency communication standards including Bluetooth, GPS, and/or others. Moreover, the one or more processor **602** may execute software code stored in the memory **606** to control such additional functionality. For example, directional velocity and/or position estimates output from a GPS receiver can be available to any application program executing on the UE **600**, including various exemplary methods and/or computer-readable media according to various exemplary embodiments of the present disclosure.

FIG. **7** is a block diagram of an example network node **700** configurable according to various embodiments of the present disclosure, including by execution of instructions on a computer-readable medium that correspond to any of the example methods and/or procedures described herein.

The network node **700** includes a one or more processor **702**, a radio network interface **704**, a memory **706**, a core network interface **708**, and other interfaces **710**. The network node **700** may comprise, for example, a base station, eNB, gNB, access node, or component thereof.

The one or more processor **702** may include any type of processor or processing circuitry and may be configured to perform any of the methods or procedures disclosed herein. The memory **706** may store software code, programs, and/or instructions executed by the one or more processor **702** to configure the network node **700** to perform various operations, including operations described herein. For example, execution of such stored instructions can configure the network node **700** to communicate with one or more other devices using protocols according to various embodiments of the present disclosure, including one or more methods and/or procedures discussed above. Furthermore, execution of such stored instructions can also configure and/or facilitate the network node **700** to communicate with one or more other devices using other protocols or protocol layers, such as one or more of the PHY, MAC, RLC, PDCP, and RRC layer protocols standardized by 3GPP for LTE, LTE-A, and/or NR, or any other higher-layer protocols utilized in conjunction with the radio network interface **704** and the core network interface **708**. By way of example and without limitation, the core network interface **708** comprise an SI interface and the radio network interface **704** may comprise a Uu interface, as standardized by 3GPP. The memory **706** may also store variables used in protocols, configuration, control, and other functions of the network node **700**. As such, the memory **706** may comprise non-volatile memory (e.g., flash memory, hard disk, etc.), volatile memory (e.g.,

static or dynamic RAM), network-based (e.g., “cloud”) storage, or a combination thereof.

The radio network interface **704** may include transmitters, receivers, signal processors, ASICs, antennas, beamforming units, and other circuitry that enables network node **700** to communicate with other equipment such as, in some embodiments, a plurality of compatible user equipment (UE). In some embodiments, the network node **700** may include various protocols or protocol layers, such as the PHY, MAC, RLC, PDCP, and RRC layer protocols standardized by 3GPP for LTE, LTE-A, and/or 5G/NR. According to further embodiments of the present disclosure, the radio network interface **704** may include a PHY layer based on OFDM, OFDMA, and/or SC-FDMA technologies. In some embodiments, the functionality of such a PHY layer can be provided cooperatively by the radio network interface **704** and the one or more processor **702**.

The core network interface **708** may include transmitters, receivers, and other circuitry that enables the network node **700** to communicate with other equipment in a core network such as, in some embodiments, circuit-switched (CS) and/or packet-switched Core (PS) networks. In some embodiments, the core network interface **708** may include the SI interface standardized by 3GPP. In some embodiments, the core network interface **708** may include one or more interfaces to one or more SGWs, MMEs, SGSNs, GGSNs, and other physical devices that comprise functionality found in GERAN, UTRAN, E-UTRAN, and CDMA2000 core networks that are known to persons of ordinary skill in the art. In some embodiments, these one or more interfaces may be multiplexed together on a single physical interface. In some embodiments, lower layers of the core network interface **708** may include one or more of asynchronous transfer mode (ATM), Internet Protocol (IP)-over-Ethernet, SDH over optical fiber, T1/E1/PDH over a copper wire, microwave radio, or other wired or wireless transmission technologies known to those of ordinary skill in the art.

The other interfaces **710** may include transmitters, receivers, and other circuitry that enables the network node **700** to communicate with external networks, computers, databases, and the like for purposes of operations, administration, and maintenance of the network node **700** or other network equipment operably connected thereto.

FIG. **8** is a block diagram illustrating components **800**, according to some example embodiments, able to read instructions from a machine-readable or computer-readable medium (e.g., a non-transitory machine-readable storage medium) and perform any one or more of the methodologies discussed herein. Specifically, FIG. **8** shows a diagrammatic representation of hardware resources **802** including one or more processors **812** (or processor cores), one or more memory/storage devices **818**, and one or more communication resources **820**, each of which may be communicatively coupled via a bus **822**. For embodiments where node virtualization (e.g., NFV) is utilized, a hypervisor **804** may be executed to provide an execution environment for one or more network slices/sub-slices to utilize the hardware resources **802**.

The processors **812** (e.g., a central processing unit (CPU), a reduced instruction set computing (RISC) processor, a complex instruction set computing (CISC) processor, a graphics processing unit (GPU), a digital signal processor (DSP) such as a baseband processor, an application specific integrated circuit (ASIC), a radio-frequency integrated circuit (RFIC), another processor, or any suitable combination thereof) may include, for example, a processor **814** and a processor **816**.

The memory/storage devices **818** may include main memory, disk storage, or any suitable combination thereof. The memory/storage devices **818** may include, but are not limited to any type of volatile or non-volatile memory such as dynamic random access memory (DRAM), static random-access memory (SRAM), erasable programmable read-only memory (EPROM), electrically erasable programmable read-only memory (EEPROM), Flash memory, solid-state storage, etc.

The communication resources **820** may include interconnection or network interface components or other suitable devices to communicate with one or more peripheral devices **806** or one or more databases **808** via a network **810**. For example, the communication resources **820** may include wired communication components (e.g., for coupling via a Universal Serial Bus (USB)), cellular communication components, NFC components, Bluetooth® components (e.g., Bluetooth® Low Energy), Wi-Fi® components, and other communication components.

Instructions **824** may comprise software, a program, an application, an applet, an app, or other executable code for causing at least any of the processors **812** to perform any one or more of the methodologies discussed herein. The instructions **824** may reside, completely or partially, within at least one of the processors **812** (e.g., within the processor's cache memory), the memory/storage devices **818**, or any suitable combination thereof. Furthermore, any portion of the instructions **824** may be transferred to the hardware resources **802** from any combination of the peripheral devices **806** or the databases **808**. Accordingly, the memory of the processors **812**, the memory/storage devices **818**, the peripheral devices **806**, and the databases **808** are examples of computer-readable and machine-readable media.

For one or more embodiments, at least one of the components set forth in one or more of the preceding figures may be configured to perform one or more operations, techniques, processes, and/or methods as set forth in the Example Section below. For example, the baseband circuitry as described above in connection with one or more of the preceding figures may be configured to operate in accordance with one or more of the examples set forth below. For another example, circuitry associated with a UE, base station, network element, etc. as described above in connection with one or more of the preceding figures may be configured to operate in accordance with one or more of the examples set forth below in the example section.

Example Section

The following examples pertain to further embodiments.

Example 1 is a method of determining a plurality of data objects, each data object corresponding to a New Radio (NR) channel using a first subcarrier spacing (SCS) and comprising an NR channel raster position and an Synchroni-

position, wherein the NR channel raster position comprises a Radio Frequency (RF) reference frequency calculated using an Absolute Radio Frequency Channel Number (NR-ARFCN); calculating Global Synchronization Channel Number (GSCN) values for the NR channel corresponding to each data object; determining a number of Physical Resource Blocks (PRBs) of the NR channel (N_{RB}) corresponding to each data object based on the first SCS and a bandwidth of the given NR channel; determining a placement for the NR channel raster position of each data object; computing the edges of each NR channel corresponding to each data object based on the center frequency of the given NR channel and the placement of the NR channel raster position of the data object; calculating the edges of an SSB of the NR channel corresponding to each data object based on the edges of the given NR channel; and determining the SSB raster position of each data object based on the edges of the SSB of the NR channel corresponding to the data object.

Example 2 is the method of Example 1, further comprising removing, from the plurality of data objects, all but a remaining one of the plurality of data objects that comprise an NR channel raster position corresponding to the same Long Term Evolution (LTE) channel raster position.

Example 3 is the method of Example 2, wherein the remaining one of the plurality of data objects that comprises an NR channel raster position that corresponds to the same Long Term Evolution (LTE) channel raster position is selected to remain because the N_{RB} of the NR channel corresponding to the data object that is equal to or greater than an N_{RB} of the NR channel corresponding to each of the other of the plurality of data objects that comprise an NR channel raster position that corresponds to the same Long Term Evolution (LTE) channel raster position.

Example 4 is the method of Example 1, further comprising removing, from the plurality of data objects, each data object that comprises an NR channel raster position that does not match an NR channel raster position of any data object of a second plurality of data objects, the second plurality of data objects each corresponding to an NR channel using a second SCS.

Example 5 is the method of any of Examples 1-4, wherein the RF reference frequencies are calculated using the formula: $F_{REF} = F_{REF-Offs} + \Delta F_{Global} (N_{REF} - N_{REF-Offs})$ wherein: F_{REF} is the given RF reference frequency; $F_{REF-Offs}$ is a reference frequency offset; ΔF_{Global} is a granularity of a global frequency raster; N_{REF} is the NR-ARFCN for the given reference frequency; and $N_{REF-Offs}$ is an NR-ARFCN offset.

Example 6 is the method of any of Examples 1-5, wherein the N_{RBS} are determined according to the following table:

SCS (kHz)	5 MHz N_{RB}	10 MHz N_{RB}	15 MHz N_{RB}	20 MHz N_{RB}	25 MHz N_{RB}	30 MHz N_{RB}	40 MHz N_{RB}	50 MHz N_{RB}	60 MHz N_{RB}	80 MHz N_{RB}	90 MHz N_{RB}	100 MHz N_{RB}
15	25	52	79	106	133	160	216	270	N/A	N/A	N/A	N/A
30	11	24	38	51	65	78	106	133	162	217	245	273
60	N/A	11	18	24	31	38	51	65	79	107	121	135

nization Signal and Physical Broadcast Channel (SSB) raster position for each NR channel; the method comprising: determining, for each data object, the NR channel raster

Example 7 is the method of any of Examples 1-6, wherein the placements for the NR channel raster positions each comprise: a physical resource block (PRB) number of a PRB

of the NR channel corresponding to the data object comprising the NR channel raster position; and a resource element index for a resource element corresponding to the NR channel raster position within the PRB.

Example 8 is the method of Example 7, wherein the resource element index for the resource element corresponding to the NR channel raster position within the PRB is determinable based on whether the number of PRBs for the NR channel corresponding to the data object comprising the NR channel raster position is even or odd.

Example 9 is the method of any of Examples 1-8, further comprising: calculating an Occupied Channel BW (OCB) of each NR channel corresponding to each data object; and determining whether a minimum guardband is available for each NR channel corresponding to each data object on both edges of the OCB of the given channel.

Example 10 is a non-transitory computer-readable storage medium, the non-transitory computer-readable storage medium including instructions that when executed by a computer, cause the computer to: determine a New Radio (NR) channel raster position for an NR channel, wherein the NR channel raster position comprises a Radio Frequency (RF) reference frequency calculated using an Absolute Radio Frequency Channel Number (NR-ARFCN); calculate Global Synchronization Channel Number (GSCN) values for the NR channel; determine a number of Physical Resource Blocks (PRBs) for the NR channel (N_{RB}) based on a subcarrier spacing (SCS) used by the NR channel and a bandwidth of the NR channel; determine a placement for the NR channel raster position; compute the edges of the NR channel based on the center frequency of the NR channel and the placement of the NR channel raster position in the channel; calculate the edges of a Synchronization Signal and Physical Broadcast Channel (SSB) of the NR channel based on the edges of the NR channel; and determine an SSB raster position of the NR channel based on the edges of the SSB.

Example 11 is the non-transitory computer-readable storage medium of Example 10, wherein the RF reference frequency is calculated using the formula $F_{REF} = F_{REF-Offs} + \Delta F_{Global} (N_{REF} - N_{REF-Offs})$ wherein: F_{REF} is the RF reference frequency; $F_{REF-Offs}$ is a reference frequency offset; ΔF_{Global} is a granularity of a global frequency raster; N_{REF} is the NR-ARFCN for the reference frequency; and $N_{REF-Offs}$ is an NR-ARFCN offset.

Example 12 is the non-transitory computer-readable storage medium of any of Examples 10-11, wherein the N_{RB} is determined according to the following table:

SCS (kHz)	5 MHz N_{RB}	10 MHz N_{RB}	15 MHz N_{RB}	20 MHz N_{RB}	25 MHz N_{RB}	30 MHz N_{RB}	40 MHz N_{RB}	50 MHz N_{RB}	60 MHz N_{RB}	80 MHz N_{RB}	90 MHz N_{RB}	100 MHz N_{RB}
15	25	52	79	106	133	160	216	270	N/A	N/A	N/A	N/A
30	11	24	38	51	65	78	106	133	162	217	245	273
60	N/A	11	18	24	31	38	51	65	79	107	121	135

Example 13 is the non-transitory computer-readable storage medium of any of Examples 10-12, wherein the placement for the NR channel raster position comprises: a physical resource block (PRB) number of a PRB of the channel corresponding to the NR channel raster position; and a resource element index for a resource element corresponding to the NR channel raster position within the PRB.

Example 14 is the non-transitory computer-readable storage medium of Example 13, wherein the resource element index for the resource element corresponding to the NR

channel raster position within the PRB is determinable based on whether the number of PRBs for the NR channel is even or odd.

Example 15 is the non-transitory computer-readable storage medium of any of Examples 10-15, the non-transitory computer-readable storage medium further including instructions that when executed by the computer, cause the computer to: calculate an Occupied Channel BW (OCB) of the NR channel; and determine whether a minimum guardband is available for the channel on both edges of the OCB.

Example 16 is a non-transitory computer-readable storage medium, the non-transitory computer-readable storage medium including instructions that when executed by a computer, cause the computer to: down select from a plurality of data objects, each data object corresponding to a New Radio (NR) channel using a first subcarrier spacing (SCS) and comprising an NR channel raster position and a Synchronization Signal and Physical Broadcast Channel (SSB) raster position for each NR channel using the first SCS, wherein down selecting is performed by removing all but a remaining one of the plurality of data objects that comprises an NR channel raster position corresponding to the same Long Term Evolution (LTE) channel raster position.

Example 17 is the non-transitory computer-readable storage medium of Example 16, wherein the remaining one of the plurality of data objects that comprise an NR channel raster position that corresponds to the same Long Term Evolution (LTE) channel raster position is selected to remain because it comprises an N_{RB} that is equal to or greater than an N_{RB} of each of the other of the plurality of data objects that comprise an NR channel raster position that corresponds to the same Long Term Evolution (LTE) channel raster position.

Example 18 is the non-transitory computer-readable storage medium of Example 16, wherein the down selecting is further performed by removing each data object that comprises a NR channel raster position that does not match an NR channel raster position of any data object of a second plurality of data objects, the second plurality of data objects each corresponding to an NR channel using a second SCS.

Example 19 may include a method of operating an NR cellular system utilizing channel raster entry among set of values of F_{REF} , where $F_{REF} = F_{REF-Offs} + \Delta F_{Global} (N_{REF} - N_{REF-Offs})$, and $\Delta F_{Global} = 15$ kHz, $F_{REF-Offs} = 3000$ MHz, $N_{REF-Offs} = 600000$, and N_{REF} is one of {744000, 745344, 746664, 748008, 749328, 750672, 751992, 753336, 754656,

754668, 754680, 756000, 765336, 766656, 766668, 766680, 768000, 769344, 770664, 772008, 773328, 774672, 775992, 777336, 778656, 778668, 778680, 780000, 781344, 783000, 784344, 785664, 787008, 788328, 789672, 790992, 792336, 793656, 793668, 793680, 744660, 746004, 747324, 748668, 749988, 750000, 750012, 751332, 752676, 753996, 755340, 765996, 767340, 768660, 770004, 771324, 772668, 773988, 774000, 774012, 775332, 776676, 777996, 779340, 780660, 783660, 785004, 786324, 787668, 788988, 789000, 789012, 790332, 791676, 792996} or {744000, 744006, 745344, 746664, 746670, 748008, 749328, 749334, 750672, 751992,

51998, 753336, 754656, 754662, 756000, 756006, 765336, 766656, 766662, 768000, 768006, 69344, 770664, 770670, 772008, 773328, 773334, 774672, 775992, 775998, 777336, 78656, 778662, 780000, 780006, 781344, 783000, 783006, 784344, 785664, 785670, 787008, 788328, 788334, 789672, 790992, 790998, 792336, 793656, 793662, 744660, 744666, 746004, 747324, 47330, 748668, 749988, 749994, 750000, 750012, 751332, 751338, 752676, 753996, 754002, 755340, 765996, 766002, 767340, 768660, 768666, 770004, 771324, 771330, 772668, 773988, 773994, 774000, 774012, 775332, 775338, 776676, 777996, 778002, 779340, 780660, 780666, 783660, 783666, 785004, 786324, 786330, 787668, 788988, 788994, 789000, 789012, 790332, 790338, 791676, 792996, 793002}

Example 20 may include the method of example 1 or some other example herein, where NR channel raster entries are selected from a subset of the entries in claim 1, where the subset is a set of values of F_{REF} , where $F_{REF} = F_{REF-Offs} + \Delta F_{Global} (N_{REF} - N_{REF-Offs})$, and $\Delta F_{Global} = 15$ kHz, $F_{REF-Offs} = 3000$ MHz, $N_{REF-Offs} = 600000$, and N_{REF} is {744000, 745344, 746664, 748008, 749328, 750672, 751992, 753336, 754668, 756000, 765336, 766668, 768000, 769344, 770664, 772008, 773328, 774672, 775992, 777336, 778668, 780000, 781344, 783000, 784344, 785664, 787008, 788328, 789672, 790992, 792336, 793668, 744660, 746004, 747324, 748668, 750000, 751332, 752676, 753996, 755340, 765996, 767340, 768660, 770004, 771324, 772668, 774000, 775332, 776676, 777996, 779340, 780660, 783660, 785004, 786324, 787668, 789000, 790332, 791676, 792996}

Example 21 may include the method of example 1 or 2 or some other example herein, where corresponding SSB raster entry for a given NR channel entry is given by “3000 MHz+N*1.44 MHz”, where N is a value from range 0 to 14756 and GSCN is given as “7499+N”, where the GSCN is K+a value from set {8996, 9010, 9023, 9037, 9051, 9065, 9079, 9093, 9107, 9121, 9218, 9232, 9232, 9232, 9246, 9260, 9273, 9287, 9301, 9315, 9329, 9343, 9357, 9357, 9357, 9371, 9385, 9402, 9416, 9430, 9444, 9457, 9471, 9485, 9499, 9513, 9513, 9513, 8996, 9010, 9023, 9037, 9051, 9065, 9079, 9093, 9107, 9218, 9232, 9246, 9260, 9273, 9287}, where K=0 . . . 6.

Example 22 may include an apparatus comprising means to perform one or more elements of a method described in or related to any of the above Examples, or any other method or process described herein.

Example 23 may include one or more non-transitory computer-readable media comprising instructions to cause an electronic device, upon execution of the instructions by one or more processors of the electronic device, to perform one or more elements of a method described in or related to any of the above Examples, or any other method or process described herein.

Example 24 may include an apparatus comprising logic, modules, or circuitry to perform one or more elements of a method described in or related to any of the above Examples, or any other method or process described herein.

Example 25 may include a method, technique, or process as described in or related to any of the above Examples, or portions or parts thereof.

Example 26 may include an apparatus comprising: one or more processors and one or more computer-readable media comprising instructions that, when executed by the one or more processors, cause the one or more processors to perform the method, techniques, or process as described in or related to any of the above Examples, or portions thereof.

Example 27 may include a signal as described in or related to any of the above Examples, or portions or parts thereof.

Example 28 may include a datagram, packet, frame, segment, protocol data unit (PDU), or message as described in or related to any of the above Examples, or portions or parts thereof, or otherwise described in the present disclosure.

Example 29 may include a signal encoded with data as described in or related to any of the above Examples, or portions or parts thereof, or otherwise described in the present disclosure.

Example 30 may include a signal encoded with a datagram, packet, frame, segment, PDU, or message as described in or related to any of the above Examples, or portions or parts thereof, or otherwise described in the present disclosure.

Example 31 may include an electromagnetic signal carrying computer-readable instructions, wherein execution of the computer-readable instructions by one or more processors is to cause the one or more processors to perform the method, techniques, or process as described in or related to any of the above Examples, or portions thereof.

Example 32 may include a computer program comprising instructions, wherein execution of the program by a processing element is to cause the processing element to carry out the method, techniques, or process as described in or related to any of the above Examples, or portions thereof.

Example 33 may include a signal in a wireless network as shown and described herein.

Example 34 may include a method of communicating in a wireless network as shown and described herein.

Example 35 may include a system for providing wireless communication as shown and described herein.

Example 36 may include a device for providing wireless communication as shown and described herein.

Any of the above described examples may be combined with any other example (or combination of examples), unless explicitly stated otherwise. The foregoing description of one or more implementations provides illustration and description, but is not intended to be exhaustive or to limit the scope of embodiments to the precise form disclosed. Modifications and variations are possible in light of the above teachings or may be acquired from practice of various embodiments.

Embodiments and implementations of the systems and methods described herein may include various operations, which may be embodied in machine-executable instructions to be executed by a computer system. A computer system may include one or more general-purpose or special-purpose computers (or other electronic devices). The computer system may include hardware components that include specific logic for performing the operations or may include a combination of hardware, software, and/or firmware.

It should be recognized that the systems described herein include descriptions of specific embodiments. These embodiments can be combined into single systems, partially combined into other systems, split into multiple systems or divided or combined in other ways. In addition, it is contemplated that parameters, attributes, aspects, etc. of one embodiment can be used in another embodiment. The parameters, attributes, aspects, etc. are merely described in one or more embodiments for clarity, and it is recognized that the parameters, attributes, aspects, etc. can be combined with or substituted for parameters, attributes, aspects, etc. of another embodiment unless specifically disclaimed herein.

It is well understood that the use of personally identifiable information should follow privacy policies and practices that are generally recognized as meeting or exceeding industry or governmental requirements for maintaining the privacy of users. In particular, personally identifiable information data should be managed and handled so as to minimize risks of unintentional or unauthorized access or use, and the nature of authorized use should be clearly indicated to users.

Although the foregoing has been described in some detail for purposes of clarity, it will be apparent that certain changes and modifications may be made without departing from the principles thereof. It should be noted that there are many alternative ways of implementing both the processes and apparatuses described herein. Accordingly, the present embodiments are to be considered illustrative and not restrictive, and the description is not to be limited to the details given herein, but may be modified within the scope and equivalents of the appended claims.

The invention claimed is:

1. An apparatus for a transceiver configured for multiple cell communication through a plurality of New Radio (NR) channels, the apparatus for determining a plurality of data objects, each data object corresponding to an NR channel using a first subcarrier spacing (SCS) and comprising an NR channel raster position and an Synchronization Signal and Physical Broadcast Channel (SSB) raster position for each NR channel, the apparatus comprising:

- a processor; and
- a memory storing instructions that, when executed by the processor, configure the apparatus to:
 - determine, for each data object, the NR channel raster position, wherein the NR channel raster position comprises a Radio Frequency (RF) reference frequency calculated using an Absolute Radio Frequency Channel Number (NR-ARFCN);

- remove, from the plurality of data objects, each data object that comprises an NR channel raster position that does not match an NR channel raster position of any data object of a second plurality of data objects, the second plurality of data objects each corresponding to an NR channel using a second SCS;
- calculate Global Synchronization Channel Number (GSCN) values for the NR channel corresponding to each data object;
- determine a number of Physical Resource Blocks (PRBs) of the NR channel (N_{RB}) corresponding to each data object based on the first SCS and a bandwidth of the given NR channel;
- determine a placement for the NR channel raster position of each data object;
- compute edges of each NR channel corresponding to each data object based on a center frequency of the given NR channel and the placement of the NR channel raster position of the data object;
- calculate the edges of an SSB of the NR channel corresponding to each data object based on the edges of the given NR channel;

determine the SSB raster position of each data object based on the edges of the SSB of the NR channel corresponding to the data object; and
 perform the multiple cell communication, through the transceiver, using the plurality of NR channels based on the plurality of data objects.

2. The apparatus of claim 1, wherein the instructions, when executed by the processor, further configure the apparatus to remove, from the plurality of data objects, all but a remaining one of the plurality of data objects that comprise an NR channel raster position corresponding to a same Long Term Evolution (LTE) channel raster position.

3. The apparatus of claim 2, wherein the remaining one of the plurality of data objects that comprises an NR channel raster position that corresponds to the same LTE channel raster position is selected to remain because the N_{RB} of the NR channel corresponding to the data object that is equal to or greater than an N_{RB} of the NR channel corresponding to each of the other of the plurality of data objects that comprise an NR channel raster position that corresponds to the same LTE channel raster position.

4. The apparatus of claim 1, wherein the RF reference frequencies are calculated using a formula

$$F_{REF} = F_{REF-Offs} + \Delta F_{Global} (N_{REF} - N_{REF-Offs})$$

wherein:

- F_{REF} is the given RF reference frequency;
- $F_{REF-Offs}$ is a reference frequency offset;
- ΔF_{Global} is a granularity of a global frequency raster;
- N_{REF} is the NR-ARFCN for the given reference frequency; and
- $N_{REF-Offs}$ is an NR-ARFCN offset.

5. The apparatus of claim 1, wherein the N_{RBs} are determined according to the following table:

SCS (kHz)	5 MHz N_{RB}	10 MHz N_{RB}	15 MHz N_{RB}	20 MHz N_{RB}	25 MHz N_{RB}	30 MHz N_{RB}	40 MHz N_{RB}	50 MHz N_{RB}	60 MHz N_{RB}	80 MHz N_{RB}	90 MHz N_{RB}	100 MHz N_{RB}
15	25	52	79	106	133	160	216	270	N/A	N/A	N/A	N/A
30	11	24	38	51	65	78	106	133	162	217	245	273
60	N/A	11	18	24	31	38	51	65	79	107	121	135.

6. The apparatus of claim 1, wherein the placement of the NR channel raster position of each data object comprises: a physical resource block (PRB) number of a PRB of the NR channel corresponding to the data object comprising the NR channel raster position; and a resource element index for a resource element corresponding to the NR channel raster position within the PRB.

7. The apparatus of claim 6, wherein the resource element index for the resource element corresponding to the NR channel raster position within the PRB is determinable based on whether the number of PRBs for the NR channel corresponding to the data object comprising the NR channel raster position is even or odd.

8. The apparatus of claim 1, wherein the instructions, when executed by the processor, further configure the apparatus to:

- calculate an Occupied Channel BW (OCB) of each NR channel corresponding to each data object; and
- determine whether a minimum guardband is available for each NR channel corresponding to each data object on both edges of the OCB of the given channel.

9. A method for communication through a transceiver based on determining a plurality of data objects, each data object corresponding to a New Radio (NR) channel using a first subcarrier spacing (SCS) and comprising an NR channel raster position and an Synchronization Signal and Physical Broadcast Channel (SSB) raster position for each NR channel, the method comprising:

determining, for each data object, the NR channel raster position, wherein the NR channel raster position comprises a Radio Frequency (RF) reference frequency calculated using an Absolute Radio Frequency Channel Number (NR-ARFCN);

removing, from the plurality of data objects, each data object that comprises an NR channel raster position that does not match an NR channel raster position of any data object of a second plurality of data objects, the second plurality of data objects each corresponding to an NR channel using a second SCS;

calculating Global Synchronization Channel Number (GSCN) values for the NR channel corresponding to each data object;

determining a number of Physical Resource Blocks (PRBs) of the NR channel (N_{RB}) corresponding to each data object based on the first SCS and a bandwidth of the given NR channel;

determining a placement for the NR channel raster position of each data object;

computing edges of each NR channel corresponding to each data object based on a center frequency of the given NR channel and the placement of the NR channel raster position of the data object;

calculating the edges of an SSB of the NR channel corresponding to each data object based on the edges of the given NR channel;

determining the SSB raster position of each data object based on the edges of the SSB of the NR channel corresponding to the data object; and

performing the communication, through the transceiver, based on one or more of the plurality of data objects.

10. The method of claim 9, further comprising, removing, from the plurality of data objects, all but a remaining one of the plurality of data objects that comprise an NR channel raster position corresponding to a same Long Term Evolution (LTE) channel raster position.

11. The method of claim 10, wherein the remaining one of the plurality of data objects that comprises an NR channel raster position that corresponds to the same LTE channel raster position is selected to remain because the N_{RB} of the NR channel corresponding to the data object that is equal to or greater than an N_{RB} of the NR channel corresponding to each of the other of the plurality of data objects that comprise an NR channel raster position that corresponds to the same LTE channel raster position.

12. The method of claim 9, wherein the RF reference frequencies are calculated using a formula

$$F_{REF} = F_{REF-Offs} + \Delta F_{Global}(N_{REF} - N_{REF-Offs})$$

wherein:

F_{REF} is the given RF reference frequency;

$F_{REF-Offs}$ is a reference frequency offset;

ΔF_{Global} is a granularity of a global frequency raster;

N_{REF} is the NR-ARFCN for the given reference frequency; and

$N_{REF-Offs}$ is an NR-ARFCN offset.

13. The method of claim 9, wherein the N_{RBS} are determined according to the following table:

SCS (kHz)	5 MHz N_{RB}	10 MHz N_{RB}	15 MHz N_{RB}	20 MHz N_{RB}	25 MHz N_{RB}	30 MHz N_{RB}	40 MHz N_{RB}	50 MHz N_{RB}	60 MHz N_{RB}	80 MHz N_{RB}	90 MHz N_{RB}	100 MHz N_{RB}
15	25	52	79	106	133	160	216	270	N/A	N/A	N/A	N/A
30	11	24	38	51	65	78	106	133	162	217	245	273
60	N/A	11	18	24	31	38	51	65	79	107	121	135.

14. The method of claim 9, wherein the placement of the NR channel raster position of each data object comprises: a physical resource block (PRB) number of a PRB of the NR channel corresponding to the data object comprising the NR channel raster position; and

a resource element index for a resource element corresponding to the NR channel raster position within the PRB.

15. The method of claim 14, wherein the resource element index for the resource element corresponding to the NR channel raster position within the PRB is determinable based on whether the number of PRBs for the NR channel corresponding to the data object comprising the NR channel raster position is even or odd.

16. The method of claim 9, further comprising: calculating an Occupied Channel BW (OCB) of each NR channel corresponding to each data object; and determining whether a minimum guardband is available for each NR channel corresponding to each data object on both edges of the OCB of the given channel.